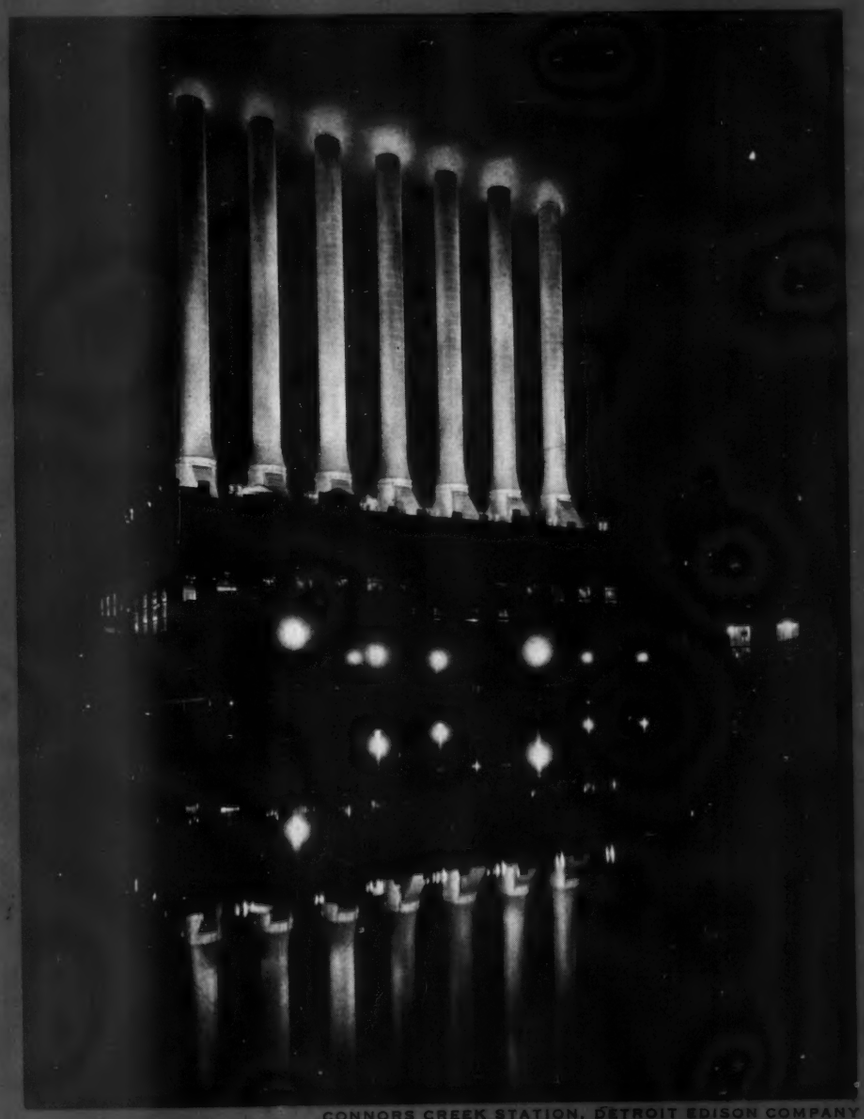
COMBUSTION

Vol. I, No. 9 MARCH 1930 MAR 8 1930 25 c. a cop

Engineering Library



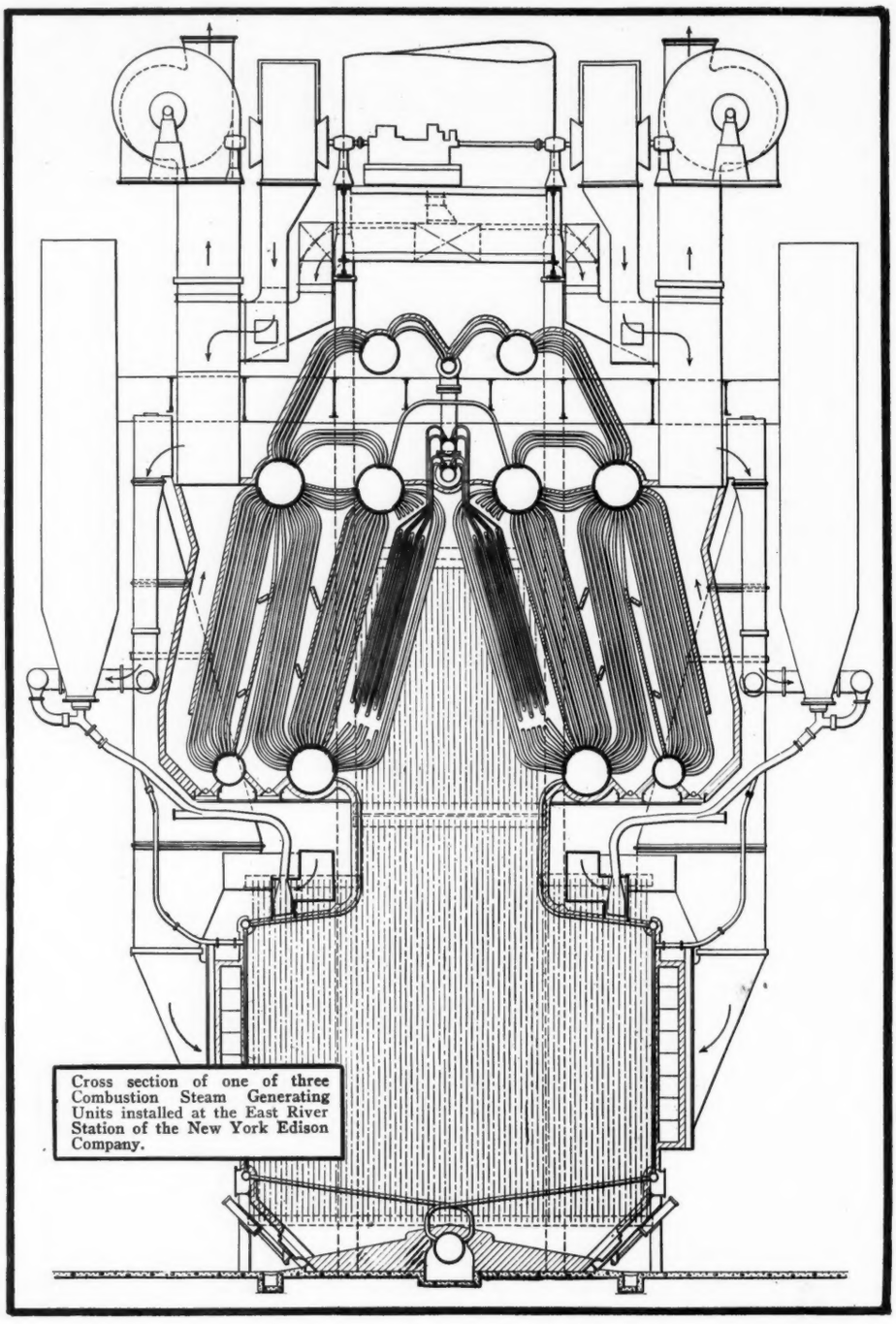
CONNORS CREEK STATION, DETROIT EDISON COMPANY

Is Soft Water the Criterion of Scale Prevention?
By A. R. MOBERG and E. M. PARTRIDGE

Natural Gas Burner Applications
By E. B. PLAPP

Problems of the Small Plant
By T. S. JARDINE and W. HUMPHRIES

Other Articles in This Issue by
W. L. DeBAUFRE • W. O. RENKIM • DAVID BROWNLIE • MERL J. CHAPMAN • B. J. CROSS



Cross section of one of three Combustion Steam Generating Units installed at the East River Station of the New York Edison Company.

This is one of the boilers that did **1,250,000** pounds of steam per hour.

We are ready to make boilers for peak loads of **1,750,000** pounds per hour each.

Combustion Engineering Corporation

200 Madison Avenue **New York, N. Y.**

COMBUSTION

Vol. 1 MARCH 1930 No. 9

CONTENTS

Feature Editorial—

Engineering 19
by Martin E. Popkin

Feature Articles—

Is Soft Water the Criterion of Scale Prevention? 21
by A. R. Moberg and E. M. Partridge

Natural Gas Burner Applications 24
by E. B. Plapp

Temperature Scales 29
by Wm. L. De Baufre

Problems of the Small Plant 34
by T. S. Jardine and W. Humphries

Fuels and Furnaces in Heat Treatment of Steel 38
by W. O. Renkin

Sulphur Fumes in Stack Gases 41
by David Brownlie

How to Determine the Conditions for the Most Economical Boiler Operation ... 44
by B. J. Cross

Installing a Stoker over the Week-end 46
by Merl J. Chapman

An Important Development in Traveling Grate Stoker Practice 47

Forty-nine Nations at World Power Conference 53

Editorials —A New Steam Capacity Record, More Power—Less Noise, Steam Gains—Hydro Loses 20

News —Pertinent Items of Men and Affairs 51

New Catalogs and Bulletins —A Review of Current Trade Publications 54

Review of New Technical Books 55

Patents—Recently Granted in United States and Great Britain 56

Advertisers' Index 63

CHARLES MCDONOUGH
Business Manager

CARL STRIPE, *Editor*

H. STUART ACHESON
General Representative

Published Monthly by

IN-CE-CO PUBLISHING CORPORATION

W. R. WOOD, *President* GEORGE H. HANSEL, *Secretary* W. I. BRANIGAN, *Treasurer*

A SUBSIDIARY OF INTERNATIONAL COMBUSTION ENGINEERING CORPORATION

NEW YORK—International Combustion Building, 200 Madison Avenue

LONDON—Africa House, Kingsway, W.C. 2

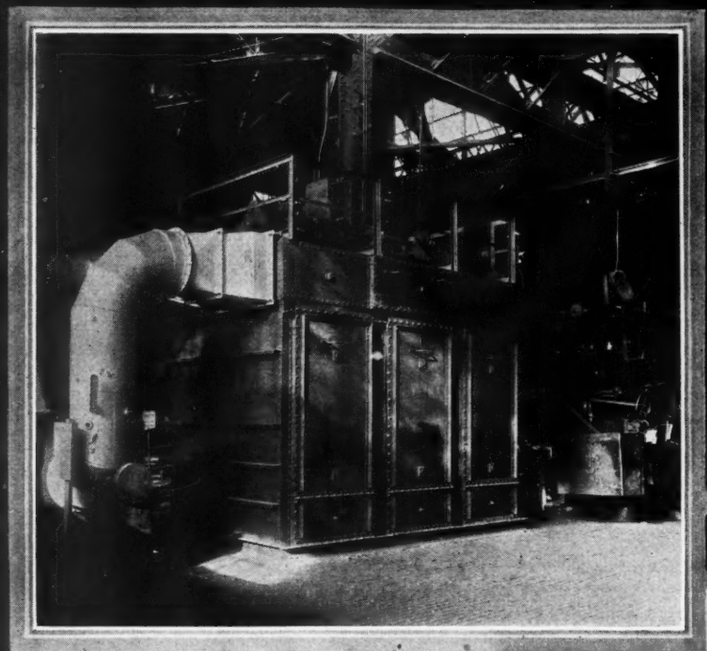
SUBSCRIPTIONS, including postage, United States and Canada, $2.00 a year, Great Britain 8 shillings. Other countries, $3.00. Single copies: United States and Canada, 25 cents. Advertising rates furnished upon application.

Copyright 1930 by In-Ce-Co Publishing Corporation, New York. Printed in U. S. A. Publication office, 200 Madison Avenue, New York.

NUMBER OF COPIES PRINTED THIS ISSUE, 11,042

A BIG MAJORITY *of the* LEADING STEEL COMPANIES *in* AMERICA

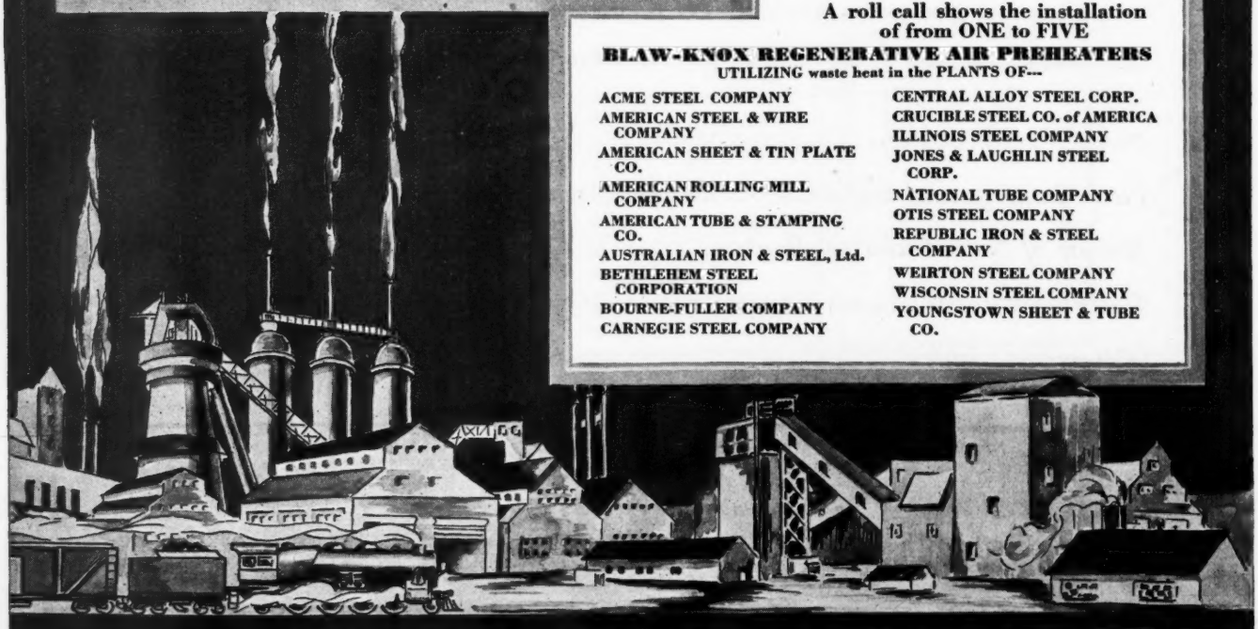
use BLAW-KNOX PREHEATERS



BLAW-KNOX
REGENERATIVE AIR PREHEATERS
are the most reliable means for heating air to high temperatures for
BILLET HEATING FURNACES
SLAB HEATING FURNACES
OPEN HEARTH FURNACES
BLAST FURNACE GAS-FIRED BOILERS
SOAKING PITS
Your selection of an AIR PREHEATER might well be guided by the experience of NINETEEN of America's leading manufacturers of steel.
Blaw-Knox Company
2039 Farmers Bank Bldg.
Pittsburgh, Pa.
Offices and Representatives in all Principal Cities

A roll call shows the installation of from ONE to FIVE
BLAW-KNOX REGENERATIVE AIR PREHEATERS
UTILIZING waste heat in the PLANTS OF—

ACME STEEL COMPANY
AMERICAN STEEL & WIRE COMPANY
AMERICAN SHEET & TIN PLATE CO.
AMERICAN ROLLING MILL COMPANY
AMERICAN TUBE & STAMPING CO.
AUSTRALIAN IRON & STEEL, Ltd.
BETHLEHEM STEEL CORPORATION
BOURNE-FULLER COMPANY
CARNEGIE STEEL COMPANY
CENTRAL ALLOY STEEL CORP.
CRUCIBLE STEEL CO. of AMERICA
ILLINOIS STEEL COMPANY
JONES & LAUGHLIN STEEL CORP.
NATIONAL TUBE COMPANY
OTIS STEEL COMPANY
REPUBLIC IRON & STEEL COMPANY
WEIRTON STEEL COMPANY
WISCONSIN STEEL COMPANY
YOUNGSTOWN SHEET & TUBE CO.



BLAW-KNOX

COMBUSTION

Vol. 1 March 1930 No. 9

Engineering

"The Art of Organizing and Directing Men and Controlling the Forces and Materials of Nature for the Benefit of the Human Race."

MARTIN E. POPKIN

"FOR the benefit of the human race." To this end all humanity dedicates its work, each in his respective calling contributing his humble part. Theology, jurisprudence, medicine, craftsmanship, the arts and the sciences; all have laid their spiritual and material offerings on the altar of life's ensemble.

Man throughout the ages, writing, singing, painting and carving with and into "the forces and materials of nature" has left eternal testimony to his inspiration—the happiness and welfare of humanity.

Dante glorified Beatrice in contemplation of womankind. Whitman acclaimed the physical quintessence of man. These are lyrics to the transcendencies of the spirit and the flesh. Rembrandt saw the rainbow and immortalized its splendor for the world. Angelo, Da Vinci, and Rodin breathed life into sleeping stone and metal.

Brahms and Beethoven, Mozart, Chopin and Wagner taught us the language of the winds and waters, and consecrated their meaning.

Science too played her part. She gave us the foundations of material concepts upon which to build the spirtual, in contrast, that we may better enjoy the one because of the existence of the other.

Engineering in husbandry of science gave the world its three dimensional poetry: The Pyramids and the Temple of Karnak under moonlight, the Taj Mahal and the Cathedral of Rheims at evening, the Palace of the Doges and the Grande Canal at sunrise, a suspension bridge at twilight, a skyscraper laughing at the clouds, a mammoth vessel at sea, a birdman with his teeth set in the tail of a north wind, a train, moving like a luminescent caterpillar in the night, an engine at play, a power plant singing its song of work.

"Organizing and directing men" that these poems may live, that the lowly and the great alike may understand. This is the heritage of the engineer.

Civilization suffering blame for decadent cultures. The grandeur of Egypt and Rome, the art of Greece,—memories, for lack of organization in the society of their times. Our era indicates vital need of organization and direction of men in the interest of culture and civilization. This is not a task for any one calling. It invites and requires the genius and cooperation of all men to the interest of a common good.

The engineer, if he is to serve this responsibility with dignity and intelligence, must understand that his work necessitates a humanitarian and artistic concept, as well as a purely utilitarian one. He is not "the priest of the machine," as Spengler would have us believe. He is a vital pillar in the cultural development of a society. He need not be any the less the pragmatist while being the poet in three dimensions. It is a glorious calling if he can shoulder these favors with humility!

Consulting Engineer, New York

EDITORIAL

A New Steam Capacity Record

SOME one has said that progress is the cumulative effect of minor achievements. Engineering progress, however, does not always move in small increments. Sometimes the forward steps are tremendous in their proportions and daring.

It took nearly fifty years to increase maximum operating steam pressures in America from 100 to 600 pounds per square inch, while during the past five years, maximum pressures increased from 600 to 1800 pounds per square inch.

The pulverized fuel fired boilers installed at the Fordson plant of Ford Motor Company held the steaming capacity record of individual units for years with an output of 600,000 pounds of steam per hour. Engineers marvelled at this capacity. Would it ever be exceeded? Could any set of conditions justify a greater concentration of power?

Within the past month one of the new boiler units at East River Station, New York Edison Company, delivered steam at the rate of 1,250,000 pounds of steam per hour.

A new steaming capacity record has been set—a capacity more than double the record which stood for years. The palm passes from an industrial to a public utility plant. The visualization and carrying out of such a project as East River reflects exceptional engineering and executive judgment.

Initiative, courage and confidence—these are essential to such engineering progress.

More Power—Less Noise

". . . and the throbbing of the mighty engines could be heard for miles around."

Thus, did an author of a half century ago reach his climax in describing a power station that had just been put into service. He sought to impress his readers with the importance of the project, by emphasizing its ability to make noise.

And, what noisy plants they were, those steam stations of the past, with the rasp of many shovels upon the fire room floor, the incessant banging of furnace doors, the panting exhaust, and the vibration of the very building itself in synchronism with the engine speed.

Mill towns once looked upon the dense clouds of smoke that poured from their chimneys, as the banners of prosperity—the blacker the smoke the fatter the pay envelopes.

In much the same manner, the noise of the old power plant was interpreted as meaning that everyone was on the job. In fact, the only time it was quiet was when something went wrong.

Recently, I visited one of the largest central station plants in the country.

The purr of the giant turbines could scarcely be heard from the street, yet each one represented perhaps a hundred times the power of those "mighty engines" of fifty years ago whose throbbing "could be heard for miles around."

The boiler room was quieter than many offices I have visited. The faint rumble of pulverizer mills in the adjoining coal preparation plant, the soft whir of coal feeders overhead and the quiet hum of pumps and auxiliaries in the basement, were the only sounds heard.

Quiet is conducive to better mental concentration and clearer thinking.

The absence of distracting noise in the modern steam station is an increasingly important contribution to better plant operation, for with higher steam pressures, larger units and higher ratings, the responsibility is enormous and there is much thinking to be done.

Steam Gains—Hydro Loses

THE total output of electricity in the United States in 1929 showed an increase of 10.7 per cent for the year, according to preliminary figures recently reported by the United States Geological Survey. The increase in 1928, as compared with 1927, was 9.3 per cent.

During 1929, the total output of electrical energy from hydro-electric plants decreased to 34,609,666,000 kw. hours (35.6 per cent of the total) as compared with 34,695,591,000 kw. hours (39.5 per cent of the total) in 1928.

In comparison, the output of electrical energy from steam stations increased to 62,684,017,000 kw. hours in 1929, over the 1928 production of 53,153,988,000 kw. hours—a gain of 18 per cent.

These figures are significant as they suggest the relative positions of our two major sources of electrical energy.

In 1929, for the first time since 1921, the production of electrical current from waterpower, fell below the output for the previous year.

In 1929, the year of greatest increase in the production of electrical energy—the entire expansion of the industry was carried by steam power.

Is Soft Water *the* Criterion *of* Scale Prevention?

By A. R. Moberg *and* E. M. Partridge

Paige & Jones Chemical Company

There seems to be an increasing interest in the subject of boiler feedwater treatment which is reflected in the attention being given to this subject in engineering society meetings and in current articles appearing in the technical press, Undoubtedly this is due to a more general realization of the importance of correct feedwater treatment and to the complexities that have been injected into the problem by new development in steam plant design and operation. In recent issues of COMBUSTION, several articles have been published in which the various methods now in use have been discussed and the more notable trends reviewed. The authors of the present article offer some interesting theories and conclusions which are well supported by actual test results and other data.

DURING the not very remote period of boiler water treatment that might be termed the "Boiler Compound Age," the sole criterion of scale prevention seemed to be based upon the practice of "Black Magic" or the sales ability of the particular concern involved in furnishing the material. It is true, however, that some manufacturers have been and still are scientifically compounding internal treatments on the basis of water analysis and plant operation.

A gradual evolution has been taking place, and the external treating plant of one type or another has rapidly come to the forefront. This might be called the "Second" or "Mechanical Period of Water Softening." The apparent criterion of scale prevention during this latter period has been soft water. Zeolitic softening seemed preferential from the standpoint of producing the softest water, but current discussion relative to corrosion, foaming and embrittlement has been gradually bringing the lime and soda or precipitation method to the fore. If soft water were to be the criterion of scale prevention, precipitation softening was secondary in efficiency to zeolitic softening and it was so regarded by the average operating engineer.

A constant endeavor has been made to produce softer water from the lime and soda equipment so as to compete with zeolitic softening by producing as low or nearly as low a hardness and at the same time maintaining a lower alkalinity. This effort has brought about the use of various coagulants which have been used in addition to the lime and soda ash with the idea of more nearly completing the reactions and obtaining a better precipitation and ultimately a softer water than was possible without their use.

With higher pressures and temperatures and with increasing amounts of research on the actual formative conditions involved in the production of scale, a third period seems to have been dawning in the rectification of boiler feed water. This period might be termed "Supplementary Treatment after Softening," and the need for such supplementary treatment was based upon the assumption that no softener could completely remove incrusting salts. It has been assumed that any reduction in residual hardness would produce a corresponding reduction in scale formation. Unfortunately, in actual practice this has not always proven true, although too often the efficiency of a precipitation process softening plant was determined by the analysis of the water obtained and not by the results obtained in actual operation. This entire subject has brought to the front questions of vital interest in the present day of high ratings and pressures.

Can a precipitation process softener be operated so as to prevent scale? Is completed reaction and softer water always or ever desirable? Is it always or ever necessary to use a supplementary treatment when using the zeolitic or precipitation methods of water softening?

Basically, the formation of scale, as well as other boiler water difficulties, is a chemical problem. Solubilities of various salts at different pressures and temperatures enter vitally into the subject of scale prevention. Preferential reactions and formation of such salts as aluminates and silicates under various temperatures are other considerations of supreme importance. These considerations, however, are entirely too technical to be forced upon the already overworked operating engineer. The entire question of scale prevention seems to be one of balancing the salts remaining in the boiler water so that concentration to preferential formation cannot produce a scale-forming condition.

A study of boiler scale samples definitely indicates the preponderance of calcium over magnesium. The less the magnesium, the harder and more dense the scale. Careful observation of the phenomena of scale formation indicates that calcium is the predominating factor in scale production. This is due in part to the lower solubility factor of magnesium hydroxide and in part to the preferential formation of non-scale-forming magnesium salts. Hall[1] states that silica will combine with magnesium to form non-adherent magnesium silicate sludge in alkaline waters. In the absence of magnesium, the silicate

[1] R. E. Hall, Hall Laboratories

will combine to produce calcium silicate which forms a hard brittle scale. Magnesium aluminate possesses a virtually insoluble non-scale-forming character, whereas the calcium aluminate readily decomposes and allows the calcium freedom for any scale-producing actions that may occur. In fact, some water chemists have actually introduced magnesium carbonate into a boiler when sodium aluminate was used as an internal treatment or when silica was present in the water so as to produce the more insoluble and non-scale-forming magnesium aluminates and silicates. From such evidence it would seem that the type of hardness is a more vital factor in scale prevention than the amount of hardness.

If, as is indicated, calcium is the most prolific scale-producing agent and if magnesium carbonate not only does not form scale itself but actually by its presence prevents the production of certain scale-forming calcium salts, it appears desirable to reduce the calcium as much as possible and leave some magnesium in the water. Accordingly, this formed the basis of further research and tests.

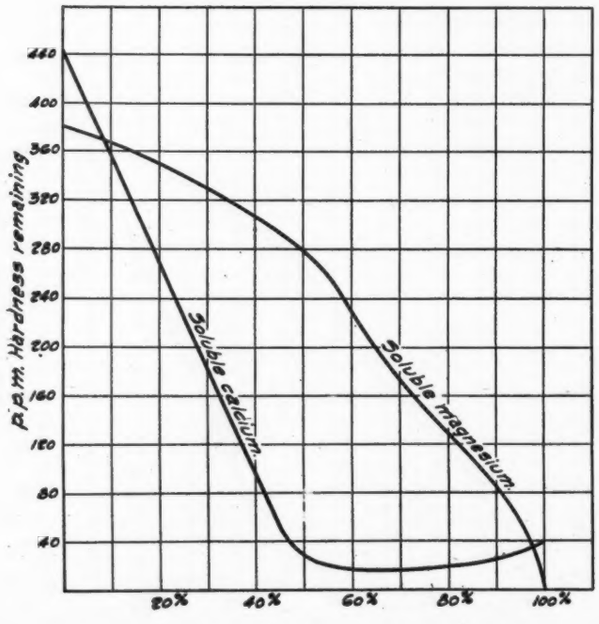


Fig. 1—Showing residual hardness with various percentages of calculated lime and soda ash added (calculated as $CaCO_3$)

In the March 20th, 1928, issue of "Power," one of the authors[2] of this article presented a series of tests made on a natural water containing both calcium and magnesium as bicarbonates and as sulphates. Having calculated the theoretical lime and soda ash requirements for this water, he added varying proportions of this amount to separate samples under exact conditions as to time, temperature, etc. Gravimetric analyses were then made on the treated water. His summation has been listed and is set forth as a graph in Fig. 1. Other tests have been made by the authors resulting in curves generally comparable.

This curve demonstrates that calcium is the first to be precipitated. The conversion of magnesium sulphate to magnesium carbonate allows virtually no precipitation of magnesium until sufficient lime has been added to satisfy the demands of the calcium bicarbonate. Beyond that point the magnesium begins to react to the hydrate and precipitates. A paper read by J. R. Baylis[3] and published in "Industrial & Engineering Chemistry" in November, 1928, deals with the solubility of calcium and magnesium at various pH values and illustrates much the same point. A paper published by Lerch and Bogue in the journal of "Physical Chemistry," Vol. 31, deals with the solubility of calcium aluminate and also indicates these features.

The feature of primary importance is that the calcium carbonate reaches its lowest solubility before the magnesium is completely precipitated, and as precipitation of magnesium is effected, the calcium carbonate increases. The presence of magnesium carbonate reduces the solubility of calcium carbonate. With this fact in mind, it will be evident that the presence of magnesium carbonate in the treated water not only allows the preferential formation of non-scale-forming salts, but actually reduces the amount of calcium remaining in the water and therefore its power to form scale.

With no excess lime and therefore no excess hydrates, the magnesium remains in partial solution as the carbonate and suppresses the solubility of calcium. When an excess of lime is added, hydrate radical appears and reduces the solubility of the magnesium. The presence of the hydrate radical and the absence of the magnesium both increase the solubility of the calcium.

It has been standard practice to use the necessary hydrate excess to reduce the total hardness to the lowest possible point.

The foregoing makes it evident that the presence of magnesium carbonate in the treated water not only allows of preferential formation of non-scale-forming magnesium salts, but actually reduces the amount of calcium in solution and thus minimizes the possibility of the formation of scale-forming calcium salts.

The efficiency of precipitation reactions is dependent upon time, temperature and coagulation. Thus, increased temperature decreases time requirements and coagulation decreases both time and temperature requirements for comparable results. Excess lime acts as a coagulant, but if at the same time it increases undesirable calcium and decreases desirable magnesium, it is evident that some other coagulant would be preferable.

It needs very little consideration of these facts to demonstrate the advantage of efficient coagulation and filtration in precipitation process softening. Obviously, there would be little advantage in re-

2 E. M. Partridge, Page & Jones Chemical Company
3 Department of Public Works, Bureau of Engineering, Chicago

ducing soluble calcium carbonate to its irreducible minimum if suspended or semi-colloidal calcium were to be left in the water. Obviously, also, the coagulant used should be capable of quick and complete reaction so that all reaction should be completed prior to filtration.

Acting upon these theories as set forth, several observation test cases were put under way. Three of these will be sufficient for illustration.

A large manufacturing plant was using an intermittent type of softener. The raw water averaged about 10 grains hardness. Lime and soda ash were used as the reagents, and as a coagulant they used a sodium aluminate solution which they made themselves. The water was used for boilers operating at 185 lb. pressure with approximately 50 per cent. make-up. Table 1 gives a representative analysis of

Table 1
Reported in ppm.

	Al_2O_3	Fe_2O_3	CaO	MgO	Hardness as $CaCO_3$
Sample 1...	0.0	0.0	14.5	0.0	24.5
Sample 2...	0.0	0.0	14.6	0.0	24.6

These samples with sodium aluminate and consequent low magnesium.

the water obtained. Note the complete absence of magnesium since the sodium aluminate used reacted with the magnesium to produce magnesium aluminate coagulum. Also note the 25 p.p.m. hardness. This water caused some slight deposit of pipe line scale and a steady accumulation of boiler scale which on analysis, was found to be primarily calcium silicate with some calcium carbonate and a trace of sulphate. In order to conform to the theories expressed above, the choice of coagulant was changed to ferric alumina. A representative analysis of the water obtained is presented in Table 2. Note the

Table 2
Reported in ppm

	Al_2O_3	Fe_2O_3	CaO	MgO	Hardness as $CaCO_3$
Sample 1...	0.0	0.0	5.3	9.3	24.6
Sample 2...	0.0	0.0	5.1	9.4	24.5

These samples with Ferric Alumina and consequent higher magnesium.

reduction in calcium and the presence of magnesium carbonate although sodium salts and hardness remained at a constant. Five months' operation with this water showed a gradual loosening of old scale and no deposition of new scale.

A central station plant using a hot process softener without any coagulant used sufficient excess lime to reduce magnesium virtually to zero and leave the hardness at an average of 1.1 grains per gallon. The resulting water produced calcium silicate scale in the boilers. The treatment was changed to increase the hardness to an average of 1.5 of which .6 grains per gallon was magnesium carbonate. Note that although the total hardness was increased, the calcium was decreased. The latter water did not produce any scale. Although no coagulant was used in this case, it was subsequently decided to use it to eliminate filter incrustations.

The third case was also a central station plant

Table 3
Reported in gpg as Ca CO_3

	$CaCO_3$	$MgCO_3$	NaOH	Na_2CO_3
Sample 1.....	1.1	.1	1.0	2.3
Sample 2.....	1.3	.2	.7	2.1
Sample 3.....	1.0	.1	1.1	2.4
Sample 4.....	1.3	0.0	1.4	2.0

using an intermittent lime-soda softener. Lime and soda with commercial sodium aluminate as the coagulant were used. Again, due to the formation of magnesium aluminate, the water was free from magnesium as is evidenced by the analysis in Table 3. Over a period of several years scale had formed on the boilers which were operated at 185 lb. pressure and from 200 per cent to 300 per cent rating with 100 per cent make-up. The scale analyses varied but always showed calcium carbonate and calcium silicate with traces of aluminum and sulphate. Again the coagulant was changed to ferric alumina to allow magnesium to remain and Table 4 shows a series of

Table 4

	$CaCO_3$	$MgCO_3$	NaOH	Na_2CO_3
Sample 1.....	.7	.6	.6	1.8
Sample 2.....	.8	.6	.7	1.5
Sample 3.....	.6	.8	.6	1.6
Sample 4.....	.6	.9	.5	1.5

representative analyses of this water. Note that in this case little reduction in Ca was obtained, which may be due to decreased sodium alkalinity. The total hardness was increased and still, over an eight-month period, no further deposit of scale occurred and much of the old scale dropped off.

From the foregoing theories, curves, and data it is evident that softness of water is not the criterion of scale prevention. It is further evidenced that relationship of solubilities in the treated water forms the basis of producing a non-scale-forming water. It is still further evidenced that scale prevention can be obtained through the medium of a precipitation process softener. It will be noted that in each of the cases presented, the boiler operating pressure was less than 200 lb.; and so it can safely be stated that supplementary treatment for scale prevention is not of necessity required at such pressures. Although the facts brought out do not deal with pressures above 200 lb., a study of solubility products shows that above 200 or 250 lb. pressure, some supplementary treatment would be indicated.

Natural Gas Burner Applications

By E. B. Plapp,

Power Engineer, American Smelting & Refining Company, El Paso, Texas

RECENT years have seen a great revival in the use of natural gas in industry. A few years ago the shortage of supply, especially for meeting winter domestic demands, brought about a curtailment in the supply of natural gas to large consumers. It was felt, and rightly so, that this ideal domestic fuel should be used as far as possible by the domestic consumer.

The last few years, however, have witnessed the discovery of large gas supplies, especially in the mid-continent fields. The great amounts of gas available, far exceeding for many years to come any possible domestic uses in the near vicinity of the wells, have caused the selling organizations of the pipe line companies to engage in active pursuit of industrial markets.

In past years, natural gas was extensively used in the steel, glass and ceramic industries of western Pennsylvania, West Virginia and Ohio. It is still used in those industries, but its use has been somewhat restricted.

The discoveries of gas in the midcontinent region have resulted in the frequent substitution of gas for coal and oil in western steel and non-ferrous smelting operations.

Every heating operation employing natural gas has two distinct functions, one in which the potential heat in the gas is changed to sensible heat through the process of combustion, and the other in which the sensible heat produced is transmitted through surfaces to the material to be heated, involving the phenomena of heat transfer. The first function is performed by burners, the second is performed by the furnace, boiler or other heat receiving equipment.

The principles of heat transfer so directly affect the design of natural gas burners that it is desirable at this point to review briefly the three methods involved, i.e., radiation, convection and conduction. Heat is first transmitted to the surfaces of materials by radiation or convection, or both, and then through the materials by conduction.

In the transmission of heat by radiation, no actual contact between flame and material is necessary but heat is transferred from flame to material by virtue of their difference of temperature and in proportion to their effectiveness as radiating bodies. Hence, it is essential in heating operations in which heat transfer by radiation predominates to provide a flame of as high a temperature as possible and of such a nature as to radiate heat rapidly.

In the transmission of heat by convection, hot gases come into intimate contact with the material to be heated. It is desirable that combustion be completed before the hot products of combustion reach and penetrate the comparatively cold material to be heated. The amount of heat extracted from the products of combustion will depend largely on the arrangement of the heat receiving surfaces, velocities of gases, etc.

Most heating operations are a combination of radiation and convection, one or the other predominating. For example, the heating of a bath of molten steel in an open hearth furnace is an example of heat transfer largely by radiation. The heating of bricks in a blast furnace stove or open hearth checkers is an example of heat transfer chiefly by convection.

Research has shown that the gases resulting from combustion of natural gas have less than ten per cent of the radiating effectiveness of so-called "Black Bodies," while gases containing finely divided carbon radiate nearly as do these "Black Bodies."

If heat is to be given off in large amounts by radiation, the gas flame must contain incandescent particles of solid carbon. These can be produced by decomposition of the natural gas. Methane, the principal component, is decomposed at 2200 deg. fahr., giving off solid carbon particles, which, being heated, are luminous to the eye and actively radiate heat.

In this connection, luminosity, or visibility to the human eye is not the real criterion of a flame's radiating capacity although our usual way of judging is by visual observation of luminosity. Much heat is actually radiated from a flame without evidence to the eye.

A luminous natural gas flame is usually produced by cracking of methane. This is accomplished by introducing natural gas into a hot furnace in such a way that mixing with air for combustion is slow By this

The use of natural gas both as a boiler fuel and for industrial heating furnaces is increasing at a rapid rate. In public utility power plants alone the consumption increased from twenty-one billion cubic feet in 1919 to over seventy-seven billion cubic feet in 1928. Sales of natural gas in 1929 were in the neighborhood of $400,000,000 and with the rapid extension of long distance pipe lines, a substantially larger market is opening up. One of the principal technical problems before the industry is gas burner design. The author of this article discusses the various types of burners used and offers some general principles governing their selection for specific applications.

means, the methane is broken up into carbon and hydrogen before oxidation is completed. A flame of this type is comparatively low in temperature.

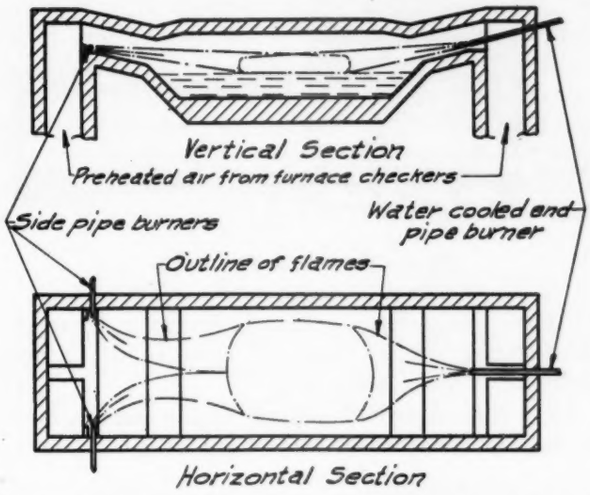


Fig. 1—Open Hearth Furnace sections showing application of pipe burners and outlines of flames

Where a luminous high temperature flame is desired, as in the steel open hearth furnace, it is necessary to preheat the air for combustion.

The theoretical flame temperature of natural gas is about 3700 deg. fahr., depending on the gas composition. The theoretical flame temperature of fuel oil is about 200 deg. fahr. higher. There is also a difference in luminosity. In changing over furnaces from fuel oil to gas, due consideration must be given to possible decrease in fuel efficiency with natural gas. The effect of the difference in flame temperatures can readily be calculated, but the effect of difference in flame luminosity is far more difficult of prediction. The writer is familiar with one instance of conversion of a large high temperature furnace from oil to gas in which the decrease in fuel efficiency was much less than expected, while he knows of other cases which did not work out so well.

Natural gas will not stand preheating as will producer gas. The cracking of the methane soon produces so much soot as to clog up any preheating equipment used. It is possible, however, to obtain satisfactory temperatures with natural gas by preheating the air supplied for combustion as has been done for years in eastern steel open hearth furnaces.

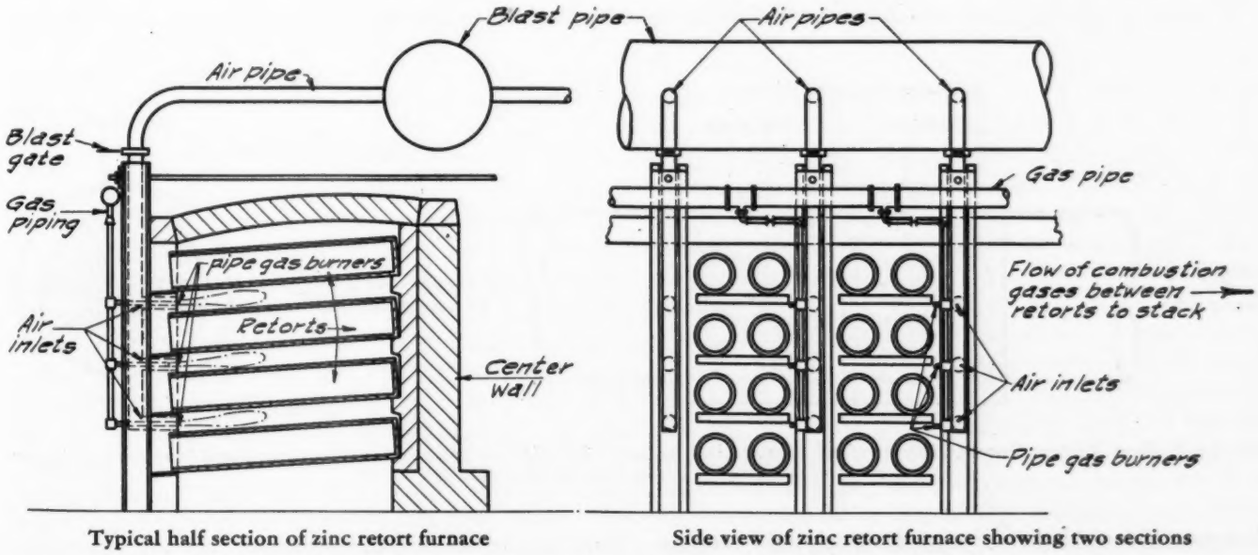
In considering the use of natural gas, the main problem is one of burner application, rather than the construction of the pipe line to the property or the selection of meters and pressure regulators. Line construction has been much simplified by the progress made in the welding art during the past few years as a result of which most gas line pipe joints are welded wherever possible. Meters and pressure regulators were highly developed in the eastern natural gas applications of years ago.

The number of types and makes of natural gas burners on the market is legion. For any prospective application of natural gas, the engineer, unless he is experienced in such work, is confronted with a great array of burners of widely differing construction and design.

This article has for its object, the enunciation of certain fundamental principles together with the application of these principles to the problem of burner choice.

No attempt is made to go into the details of burner construction. The examples used are made only to illustrate the principles discussed, as details of application must depend on the particular problem involved.

In considering the application of natural gas to any heating operation, assuming that the size, shape



Typical half section of zinc retort furnace

Side view of zinc retort furnace showing two sections

Fig. 2—Zinc Retort Furnace using pipe burners. Furnace temperatures of about 2,300 deg. fahr. are secured

and general design of furnace have been decided upon, the first point to be ascertained is the predominant method of heat transfer in the application under consideration, for this determines the type of flame desired. As the type of flame produced is determined by the rapidity and thoroughness of mixture of gas and air produced by the burner, it is evident that the type of burner to be applied can usually be determined by considering the degree of mixture of gas and air required.

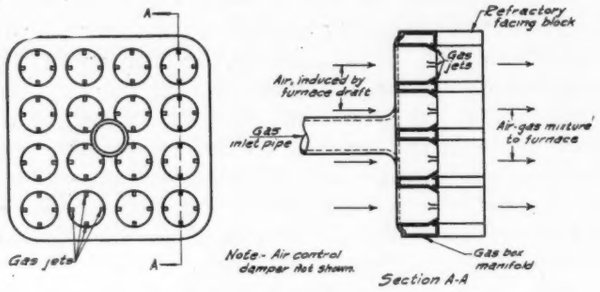


Fig. 3—Slow Mixing Burner

A burner producing a rapid, intimate mixture of gas and air will have a short, non-luminous flame of high temperature, usually suitable for applications where convection predominates as the heat transfer method, but also applicable where radiation from a hot furnace wall or roof can be utilized to transfer heat received from the flame to the material to be heated. It has been proposed to carburet the high temperature non-luminous flames from burners of this type with a small percentage of fuel oil, to produce luminous flame, but the writer knows of no applications of this sort.

Burners producing little mixing effect will produce long, luminous flames of comparatively low temperature with cold combustion air, but suitable for high temperature applications when preheated air is used.

The many types and makes of burners can all be classified on the basis of the intimacy of mixture of gas and air in the burner.

It will be realized that there are many other bases of classification, such as, according to the gas and air pressures employed, whether or not refractories

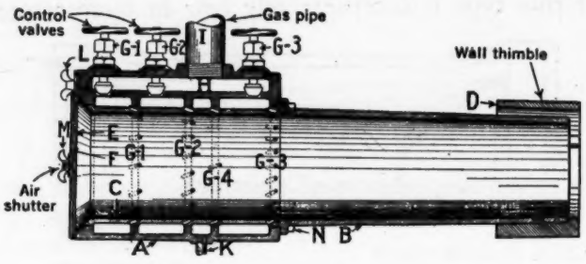


Fig. 4—Slow Mixing Type Burner

are used, etc. It is believed, however, that the classification on the basis of rapidity of mixture produced is most applicable.

As to their degree of mixture of gas and air, burners may be classified according to:

1. pipe burners.
2. slow mixing type.
3. medium mixing type.
4. rapid mixing type.

It is understood that these divisions are not closely drawn; they merely provide a simple, easily remembered, basis of classification.

Pipe Burners

This type of burner is extensively used in the steel open hearth furnace as shown in Fig. 1. In some furnaces the gas enters at the ends and mixes with the hot air coming from the checkers. In other furnaces, the gas enters at the sides. It will be noted that mixing takes place slowly, along the division lines of the air and gas streams. As the velocities are comparatively low, there is no turbulence, the flow of gas and air being largely in straight lines. Hence, mixture is poor. Because of the high preheat temperature of the air, the methane is decomposed and a luminous flame results which is advantageous for rapid heat transmission to the furnace

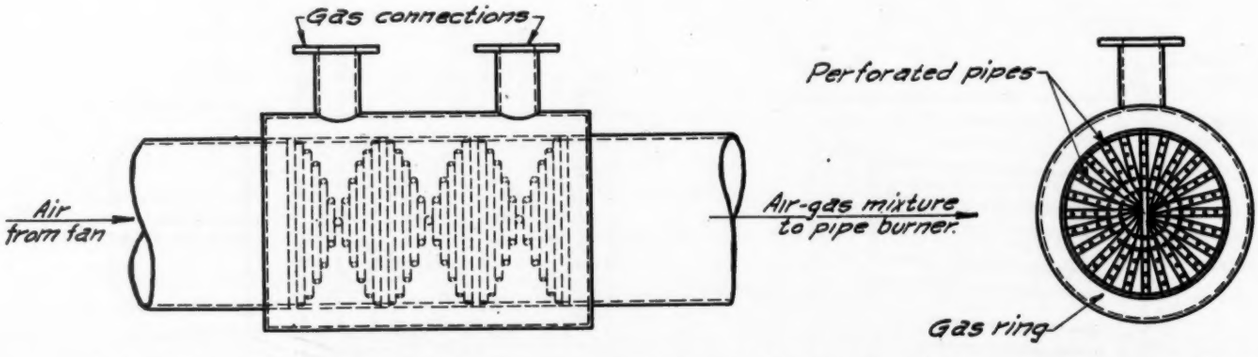


Fig. 5—Medium Mixture Burner. Burners of this type use both gas and air under low pressures and have considerably more capacity per sq. ft. of burner cross section than the slow mixing type

bath. Furnace temperatures in excess of 3000 deg. fahr. are produced in these furnaces.

The common zinc retort furnace is another example of this method of burning. As shown in Fig. 2, gas and air are admitted along the furnace and allowed to mix. Here again, mixture is slow. This does not work to any disadvantage as far as flame temperature is concerned for it is necessary in this type of furnace to avoid injury to the retorts by preventing local high temperature points. Furnace temperatures of 2300 deg. fahr. are produced in such furnaces.

Slow Mixing Type Burners

Some types of boiler burners are of the slow mixing type. One well known type is illustrated in Fig. 3. In this burner, air enters through a series of holes, and gas is injected into the air streams. Here again, the gas and air velocities are so low that air and gas flow in parallel streams and slow mixing results. However, for boiler application, the results are satisfactory. Extremely high furnace temperatures are not required and the conditions secured are such as to prevent undesirable local hot spots or impingement of flame on the tubes. The slow mixing gives a fairly luminous flame, increasing the proportion of heat transmitted by radiation to the exposed boiler tubes.

Another common type is shown in Fig. 4. Here again, air is drawn in through the center of the burner while gas is injected around the outside. Mixing is slow because the gas velocity is too low to penetrate and thoroughly mix with the air stream.

In other burners for similar application the gas enters in the center of the air stream instead of around the outside as in the burners illustrated. The general principle and results are the same in the two burners. Gas and air enter in parallel streams and at nearly equal velocities, giving slow mixing. Furnace temperatures of about 2400 deg. fahr. are reached with burners of this type.

Medium Mixing Burners

In this type of burner, mixing is somewhat more rapid than in the type just described. The resulting flame is but faintly luminous. Burners of this type use both air and gas under low pressures, usually not more than a few ounces. Because of this they have considerably more capacity per sq. ft. of burner cross section than the type just described.

A good example of this type is the design much used in cement kilns and shown in Fig. 5. It will be noted that gas is injected into the central air stream from the gas chamber surrounding the air pipe. This burner has been made quite elaborate. In the design shown, gas is introduced from holes in pipes running diametrically through the central air passage, the pipes being connected at both ends to the surrounding gas space. The pipes are staggered to give the whole mass of gas and air a twisting motion, the purpose being to assure more complete mixing.

Burners of this type give fairly high flame temperatures, although not as high as those of the burners next to be described.

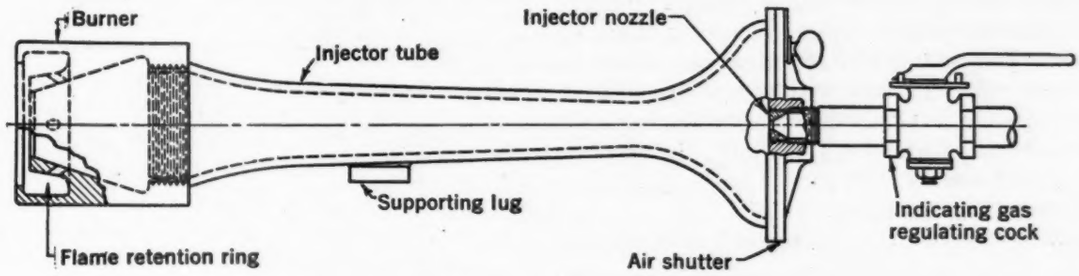


Fig. 6—Combined Mixer and Burner "Venturi" Type

Rapid Mixing Burners

Rapid mixing burners are represented by the so-called "Venturi" type. In one example of this type, illustrated in Fig. 6, a high pressure jet of gas is used to entrain air from the atmosphere. The action of air entrainment is purely a dragging in of air, with the stream of gas, at the surface of the gas jet. For natural gas, it has been found that a gas pressure of at least 10 lb. per sq. in. is necessary to entrain sufficient air for complete combustion at high burner capacity and that, in large burners, 20 lb. pressure is desirable.

Burners of this type produce a short, intensely hot, non-luminous flame. The mixer and burner are often combined, as shown in Fig. 6, but more frequently are made in two parts, the mixer and the burner proper. The burner proper often consists of a simple nozzle so proportioned as to prevent backfire. It is also modified as shown in Fig. 6 with a special tip whose function it is to prevent blowing out the flame.

In some modifications of this type, such as that shown in Fig. 7, the mixing is done in two stages. This gives some control of length of flame by varying the proportions of air introduced at the two stages.

This burner is largely self-proportioning, requiring a single adjustment, that of the gas pressure.

Burners of similar construction, in which a stream of air under pressure is used to entrain the gas for combustion, are used in great numbers on small and medium sized heating furnaces. A burner of this type is illustrated in Fig. 8.

In one large furnace employing burners of this type without preheating the air for combustion, the writer has noted furnace temperatures of about 2800 deg. fahr.

The modifications of the above several types are too numerous to include in this article. There are certain principles, however, which seem to stand out.

With gas and air admitted under comparatively low pressures and velocities and in parallel streams, mixing is slow because the relative motion of gas to air is low. The flow is not turbulent but rather in straight lines with consequent slow mixing. Where either gas or air is admitted under comparatively high pressure and hence high velocity, the relative velocity of the one to the other is high, producing turbulence and rapid mixing.

In order to obtain good combustion, careful control of the proportions of air and gas must be maintained. In all but the type of burner shown in Figs. 6, 7 and 8, this involves careful control of gas pressures, furnace drafts, and air pressures. In the type shown in Figs. 6 and 7, the burner is largely self-adjustable under varying gas pressures and hence, the only important adjustment, once the primary and secondary air shutters have been adjusted, is that of the high-pressure gas.

From the foregoing, it is evident that when a luminous flame is desired, combustion must be delayed, the methane gas being partially decomposed. If, also, the flame must be of high temperature, say from 3000 to 3100 deg. fahr. as in the steel open hearth furnace, preheated air must be employed. If

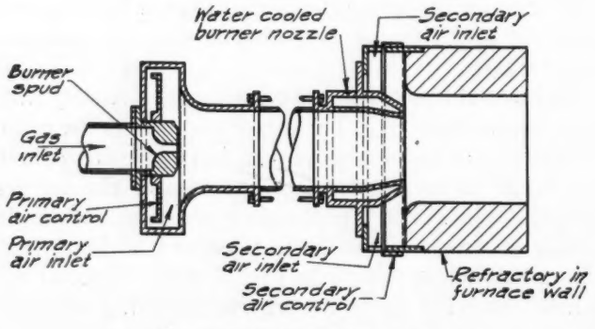


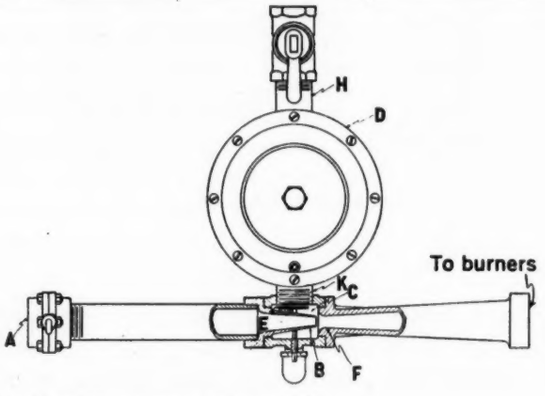
Fig. 7—Two Stage Rapid Mixing Burner

the application does not require furnace temperatures above about 2300 deg. fahr., the slow or medium mixing types may be used where the combustion space is relatively large, and it is not desirable to allow the flame to impinge directly on the heat receiving surfaces. In this class of application are boilers, dryers, revolving kilns, etc.

It must be remembered that in all slow or medium mixing burners, careful control of gas and air pressure and furnace draft are necessary for complete combustion without too much excess air.

For applications requiring short, intense flames without luminosity, rapid mixing burners are used. Furnace temperatures of 2700 deg. fahr. to 2800 deg. fahr. can be obtained without air preheating. The flames from these burners can also be made to impinge directly upon the material being heated, producing rapid heat absorption.

This type of burner is extensively used in steel heating, annealing and forging furnaces and in nonferrous melting operations. The self-proportioning



A—Air pipe, pressure 4 in. to 4 lb.
B—Air jet.
C—Suction chamber.
D—Gas pressure governor (gas maintained at atmospheric pressure).
E—Adjustable orfice.
F—Diverging sleeve.
H—Gas line.
K—Gas chamber.

Fig. 8—Rapid Mixing Burner using air under pressure

feature of this burner is of great advantage in simplifying control of air and gas proportions.

In conclusion, the writer wishes to offer a suggestion from his experience to prospective users of gas burning equipment. With coal or oil, lack of sufficient air for combustion is immediately shown by smoke. With natural gas, a great amount of gas may be escaping unburned without much evidence of poor combustion. The ordinary three chamber Orsat gas analysis equipment, as used in boiler tests to analyse for carbon dioxide, oxygen and carbon monoxide, does not give sufficient information to detect losses. Under certain conditions hydrogen and methane also may be escaping. A five chamber Orsat with a combustion pipette will often give valuable information.

Temperature Scales

By Wm. L. De Baufre*

International Combustion Engineering Corporation, New York

Operating and designing engineers are frequently faced with problems which call for a more intimate understanding of basic engineering principles than is generally acquired in undergraduate days and in the years of more or less specialized experience that follow. It is the purpose of this series of articles by Mr. De Baufre to review the fundamentals of thermodynamics in the light of present day knowledge and to thus provide the necessary background for a more enlightened application of these principles to the problems of steam plant design and operation.

OUR first conception of temperature is obtained through the sense of touch—we say that a body is hot or cold according to the way it feels. We also associate the idea of temperature with the sense of sight by saying that a furnace is at a red heat or at a white heat. Industrial operations are sometimes controlled by the workman according to a "color scale" of temperature. Our senses, however, have very limited ranges and are not reliable. In spite of this fact, it is only within the past 300 years that instruments have been developed to indicate temperatures. Thus, the invention of the mercury-in-glass thermometer is attributed to Galileo about 1612.

Modern engineering and scientific work requires accurate temperature measurements, and these measurements must be made in accordance with an accepted temperature scale. It is the purpose of this article to trace briefly the development of the present universally accepted temperature scales. The instruments used will be described only to the extent necessary to show the reasons for the temperature scales adopted.

Fahrenheit and Centigrade Temperature Scales

Two temperature scales are extensively used in the United States, namely, the fahrenheit scale and the centigrade scale. A third scale, the reaumur, is rarely referred to in this country. These scales are determined by two fixed points and the number of degrees between them.

Fahrenheit in 1714 proposed to take the lowest temperature obtainable with a freezing mixture of ice and common salt as the lower fixed point and mark it zero on a temperature scale. He followed Galileo in taking the temperature of the human body as the upper fixed point. This interval was at first divided into 12 degrees and later into 96 degrees. Fahrenheit found that the freezing point of water was constant and the boiling point was always the same under the same atmospheric pressure. These he found to be 32 and 212 degrees respectively. Shortly after Fahrenheit's death in 1736, the freezing and boiling points of water became generally recognized as the most convenient fixed points to adopt for the determination of temperature scales. On the centigrade scale introduced by Celsius in 1742, the distance between these two fixed points was divided into 100 degrees and the temperature of melting ice, at first indicated as 100, is now marked zero.

The relation between the fahrenheit and centigrade temperature scales is given by

$$\frac{F-32}{180}=\frac{C}{100}$$

where F and C represent the readings on the fahrenheit and centigrade scales respectively of a thermometer at a given temperature. The correctness of this relation becomes evident by an inspection of Fig. 1.

As the melting point of ice varies only about 0.00001 degree centigrade for each millimeter of mercury change in atmospheric pressure, no correction is usually necessary for ordinary variations in atmospheric pressure when marking the ice point on a thermometer immersed in melting ice. The boiling point of water, however, varies considerably with the pressure to which it is subjected. Instead of immersing the thermometer in boiling water, it is suspended in the steam generated therefrom and a correction applied if the pressure of the condensing steam differs from normal atmospheric pressure (760 mm. of mercury). The variation of the temperature of condensing steam around atmospheric pressure is given by

$$t=100+0.0367\,(p-760)-0.000023\,(p-760^2)$$

where t is in degrees centigrade and p is in millimeters of mercury. The variation in temperature from 700 to 820 mm. of mercury (27.5 to 32.3 mm. of mercury), is shown in Fig. 2.

The Mercury-in-Glass Temperature Scale

Alcohol was at first employed for the liquid in thermometers, and is so used today, particularly for measuring temperatures that are liable to drop below the freezing point of mercury. Mercury is preferred, however, chiefly because of its high boiling point which may be raised even above the softening temperature of glass by the use of a neutral gas in the thermometer.

Mercury-in-glass thermometers are made by welding to a glass tube having a very small bore, a thin-walled bulb having a volume suitable for the temperature range and scale desired. The thermometer is filled with mercury by heating the bulb to drive

*All rights reserved by the author.

out the air and then inverting the thermometer in a mercury bath. This process is repeated until all air is expelled as evidenced by the absence of air bubbles in the bulb and stem. The bulb is then subjected to a temperature slightly above the upper limit of the range desired, some of the mercury being ejected by expansion, and the tube is sealed. After heat treatment to relieve strains set up in the glass, the thermometers are ready for graduating with the scale range and intervals desired.

If a mercury-in-glass thermometer is graduated by marking on the stem the heights of the mercury column with the thermometer immersed in condensing steam under normal atmospheric pressure and then in melting ice, by dividing the distance between these two marks into 100 or 180 equal parts according to the scale desired, and by extending the divisions above and below the two original marks, the resulting scale is known as the mercury-in-glass temperature scale. Even after applying corrections, however, for irregularity in the bore of the tube, etc., this temperature scale was found indefinite by reason of variations in the coefficient of expansion

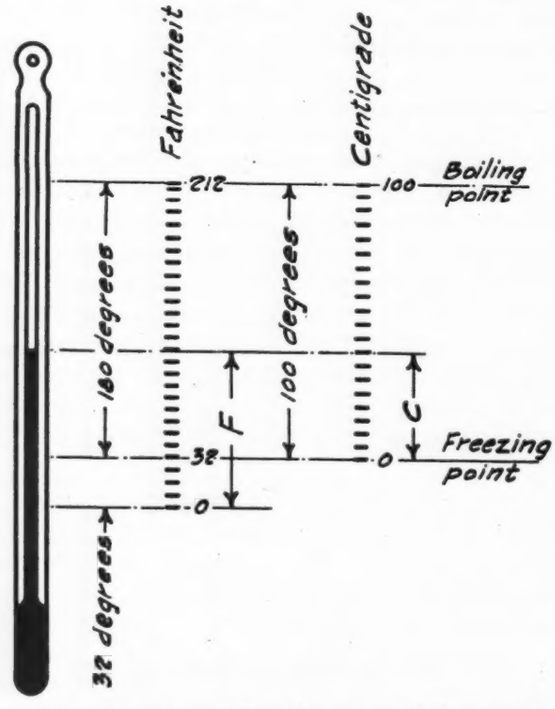


Fig. 1—Relation between fahrenheit and centigrade temperature scales

of glass. Also, liquids other than mercury gave different readings for the same temperatures between and beyond the two fixed points.

The Gas Temperature Scale

The researches of Gay-Lussac in 1802 and of Regnault in 1847 showed that gases expand in a much more regular manner than liquids. In order to secure greater precision in temperature measurements, a gas temperature scale was therefore made the standard of reference. The following resolution was adopted October 15, 1887: "The International Committee on Weights and Measures adopts as the standard thermometric scale for the international service of weights and measures, the centigrade scale of the hydrogen thermometer having as fixed points the temperatures of melting ice (0°) and of the vapor of distilled water boiling (100°) at standard atmospheric pressure, the hydrogen scale being taken at an initial manometric pressure of one meter of mercury—that is to say, 1000/760=1.3158 times the standard atmospheric pressure." It was necessary to specify the pressure of the hydrogen at ice melting temperature because the scale varies slightly with the initial gas pressure. Other gases have been used to determine temperature scales such as nitrogen for high temperatures and helium for very low temperatures, the results then being stated in terms of the nitrogen gas scale and the helium gas scale respectively.

The Thermodynamic Temperature Scale

Even hydrogen, however, is not a perfect gas, so a thermodynamic temperature scale was proposed by Lord Kelvin in 1848, which would be independent of any particular substance. In accordance with Carnot's reflections on the motive power of heat, all perfect heat engines will perform equal amounts of work with the same initial and final temperatures, and equal quantities of heat taken in at the initial temperature, irrespective of the nature of the engines or of the mediums employed therein. Hence, if the temperature divisions between the fixed points of condensing steam and melting ice are determined by making the intervals correspond to equal amounts of work performed by a series of perfect heat engines working between the two fixed points, each engine taking in at its initial temperature the quantity of heat rejected by the preceding engine at its final temperature, a thermodynamic temperature scale is defined which is independent of any particular substance. This scale would correspond to that defined by the expansion of a "perfect gas."

As the definition of the thermodynamic temperature scale is based upon ideal conditions, it becomes necessary to determine what corrections must be applied to measurements with actual thermometers in order to realize this temperature scale. Lord Kelvin accordingly devised an experiment to show the departure of any gas from the laws of a "perfect gas." Utilizing the results of such experiments, the melting and boiling points of various pure substances have since been determined on the thermodynamic temperature scale.

The International Temperature Scale

The International Temperature Scale was adopted October 4, 1927, by the General Conference of Weights and Measures representing the various countries of the world. The Thermodynamic Centigrade

Scale was recognized as the fundamental scale to which all temperature measurements should ultimately be referable. The experimental difficulties incident to the realization of the thermodynamic scale made it expedient to adopt for international use a practical scale designated as the International Temperature Scale based upon a number of fixed and reproducible equilibrium temperatures to which numerical values are assigned, and upon the indications of interpolation instruments calibrated according to a specified procedure at the fixed temperatures.

The basic fixed points are the equilibrium temperatures between

(a) Liquid and gaseous oxygen . . —182.97 cent.
(b) Ice and air-saturated water . . 0 cent.
(c) Liquid water and its vapor . . 100 cent.
(d) Liquid sulphur and its vapor . 444.60 cent.
(e) Solid silver and liquid silver . 960.5 cent.
(f) Solid gold and liquid gold . . . 1063 cent.

The above given numerical values correspond to a pressure of one standard atmosphere (760 mm. of mercury). Relations between temperature and pressure are given for calculating the equilibrium temperatures under other than standard atmospheric pressure, but these relations have not been included in this article.

From the ice point to 660 cent., the interpolation instrument specified is a platinum resistance thermometer. This instrument is based upon the fact that the resistance to flow of electric current through a wire is a function of the temperature of the wire. The first practical form of pyrometer based on this principle was constructed by Sir William Siemens in 1871. The temperature in degrees centigrade on the International Temperature Scale is deduced from the measured resistance Rt by means of the formula

$$Rt = Ro\,(1 + At + Bt^2)$$

The constants Ro, A and B of this formula are to be determined by calibration at the ice, steam and sulphur points. The purity and physical condition of the platinum of which the thermometer is made is specified to be such that the ratio Rt/Ro shall not be less than 1.390 for t = 100 cent. and not less than 2.645 for t = 444.6 cent.

From —190 cent. to the ice point, the temperature t is also to be deduced from the resistance Rt of a platinum resistance thermometer, but by means of a somewhat different formula, namely,

$$Rt = Ro\,[1 + At + Bt^2 + C\,(t - 100)\,t^3]$$

The constants Ro, A and B are to be determined as specified above, and the additional constant C is to be determined by calibration at the oxygen point. The platinum must, in addition, have a ratio Rt/Ro less than 0.250 for t = — 183 cent.

From 660 cent. to the gold point, the temperature on the International Temperature Scale is to be deduced from the electromotive force of a thermocouple employing wires of platinum and platinum-rhodium. One junction of the thermocouple is to be kept at zero centigrade while the temperature t of the other junction is to be taken as related to the measured electromotive force e according to the relation

$$e = a + bt + ct^2$$

The constants a, b and c are to be determined by calibration at the freezing point of antimony and at the silver and gold points.

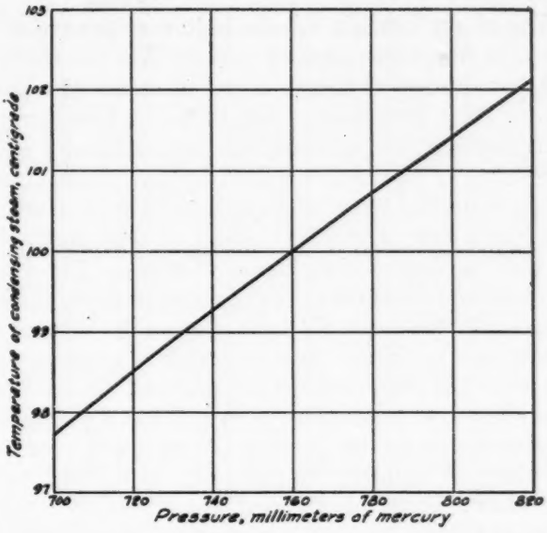


Fig. 2—Variation of temperature with pressure of condensing steam

The thermocouple is based on a discovery made about one hundred years ago by T. J. Seebeck that an electric current will flow in a closed circuit composed of two different metals if the junctions of the metals are at different temperatures. It was later found that two causes contribute to the electromotive force which produces the electric current. First, an electromotive force exists between different metals in contact, the magnitude of which depends upon the temperature of the junction and the kinds of metals used. Second, when a wire of homogeneous metal is heated at one end, an electromotive force is set up between the hot and cold ends of the wire, the magnitude of which depends upon the temperature difference between the hot and cold ends and the kind of metal in the wire. The first is known as the Peltier effect, being the discovery of J. C. A. Peltier in 1834 that heat is absorbed at the junction of two metals by passing a current through it in the same direction as the current produced in heating it. The second is the Thomson effect discovered by Lord Kelvin in 1851 and experimentally demonstrated by him several years later. The thermocouple composed of one wire of pure platinum and one wire of platinum containing 10 per cent of rhodium, was first proposed by Le Chatelier in 1886.

Above the gold point, the temperature t on the International Temperature Scale is to be determined by means of the ratio of the intensity J_1 of monochromatic visible radiation of wave length λ cm. emitted by a black body at the temperature t_1, to the intensity J_1

of radiation of the same wave length emitted by a black body at the gold point, by means of the formula

$$\log_e \frac{J_2}{J_1} = \frac{C_2}{\lambda}\left[\frac{1}{1336} - \frac{1}{(t+273)}\right]$$

The constant C_2 is to be taken as 1.432 cm. degrees. The equation is valid if the wave length λ cm. is such that $\lambda(t+273)$ is less than 0.3 cm. degrees.

The above formula for the radiation pyrometer is based on the expression derived by Wein in 1896 for the distribution of energy in the spectrum of a black body. Wein's expression was found by Lummer and Pringsheim in 1899 to hold true experimentally when $\lambda(t+273)$ is less than 0.3 cm. degrees. This condition is complied with by optical pyrometers in which the brightness of the hot object is compared with that of an incandescent lamp filament. The value 1.432 for the constant C_2 is the result of many experiments. Monochromatic light is generally secured by means of a red filter glass although a spectroscopic eye piece has been used for the purpose. Black body conditions are practically obtained by sighting the radiation pyrometer through a small hole into an inclosure of uniform temperature. If sighted upon a solid or a liquid in the open, the measured temperature is below the true temperature of the solid or liquid because the emissivity of any substance is less than that of a "black body".

In addition to the basic fixed points, a number of secondary points for the International Temperature Scale with the equilibrium temperatures under one standard atmospheric pressure are given as follows:

Solid and gaseous carbon dioxide	—78.5	cent.
Freezing mercury	—38.87	cent.
Transition of sodium sulphate	32.38	cent.
Condensing napthalene vapor	217.96	cent.
Freezing tin	231.85	cent.
Condensing benzophenone vapor	305.9	cent.
Freezing cadmium	320.9	cent.
Freezing lead	327.3	cent.
Freezing zinc	419.45	cent.
Freezing antimony	630.5	cent.
Freezing copper in a reducing atmosphere	1083.	cent.
Freezing palladium	1555.	cent.
Melting tungsten	3400.	cent.

Thermal Expansion of Solids and Liquids

Probably the most noticeable effect of temperature change is the expansion and contraction of solids and liquids. Railroad rails laid in winter must have spaces left at their ends so that when they expand with rise of temperature during the summer, they will not butt together and buckle. In designing piping systems for conveying steam, provision must be made for change in length of the pipes between room temperature and that corresponding to the pressure of the steam conveyed. The relation between length and temperature is given by

$$L_2 = L_1(1+\alpha t)$$

in which L_1 = original length,
t = change in temperature,
α = coefficient of linear expansion and
L_2 = final length.

The coefficient of linear expansion α may be defined as the increase in length per unit length per degree temperature rise. The value of the coefficient per degree fahrenheit will evidently be five-ninths of the value per degree centigrade for the same material.

The variation in area of a surface with change of temperature may be represented by

$$A_2 = A_1(1+\beta t)$$

in which A_1 = original area,
t = change in temperature,
β = coefficient of superficial expansion and
A_2 = final area.

Consider the area A_1 to be a square having sides of length L_1, then $A_1 = L_1^2$. When the temperature changes t degrees, L_1 will increase to L_2 and $A_2 = L_2^2$. Substituting the values of L_2 from the formula for linear expansion, we have

$$A_2 = L_2^2 = L_1^2(1+\alpha t)^2 = A_1(1+2\alpha t+\alpha^2 t^2).$$

Since α is a small quantity, less than 0.0001 per degree centigrade with but few exceptions, α^2 is very small and the term $\alpha^2 t^2$ may be neglected. Comparing the two expressions for A_2, we find

$$\beta = 2\alpha \text{ (approximately).}$$

In a similar manner, volume changes with temperature variations may be represented by

$$V_2 = V_1(1+\lambda t)$$

and the coefficient of volumetric expansion is approximately three times the coefficient of linear expansion, that is,

$$\lambda = 3\alpha \text{ (approximately)}$$

The coefficients of expansion of solids and liquids vary greatly; for example, the operation of the mercury-in-glass thermometer depends upon the fact that mercury has a coefficient of volumetric expansion of 0.000182 per degree centigrade while that of glass is only about 0.000025. Mercury-in-glass thermometers are generally graduated for total immersion. It is often necessary to use them, however, with the bulb and only part of the stem immersed in the material of which the temperature is desired. Let t be the temperature of the bulb. Then t represents the number of degrees on the stem where the mercury column would stand were the thermometer totally immersed. Let t_o be the number of degrees to which the stem is immersed. If the mean temperature of the exposed portion of the stem be t_s instead of t, then the mercury column $(t-t_o)$ will be shortened a distance s equal to the product of its original length $(t-t_o)$, its reduction in temperature $(t-t_s)$ and the mean coefficientof relative expansion α of mercury in glass; that is,

$$s = \alpha(t-t_s)(t-t_o)$$

If the observed temperature reading of a thermometer with an exposed stem be substituted for t in the above formula, an approximate value of t is obtained

which may be applied to the reading as an exposed stem correction in order to obtain an approximately true value of the temperature desired. If the correction is large, it may be desirable to recalculate it by substituting for t the first approximation to the true temperature. For ordinary thermometer glass, the value of α may be taken as 0.000157 per degree centigrade equivalent to 0.000087 per degree fahrenheit.

Thermal Expansion of Gases

Robert Boyle was the first one to investigate scientifically the expansion and compression of gases. He was unable to determine the effect of temperature change because no temperature scale had been defined when he made his experiments in 1662. He showed, however, that when the temperature remains constant, the volume of a given mass of gas varies inversely as the pressure. Boyle's law is generally expressed as

$$PV = C$$

where P is the pressure supported by a gas, V is its volume and C is a constant for each particular temperature. More recent experiments demonstrate that gases deviate from Boyle's law as they approach liquefaction.

The expansion of gases with change in temperature was first investigated by Dalton and by Gay-Lussac, the latter announcing in 1802 the law generally known by his name. Later researches, particularly by Regnault, have shown that this law is very nearly correct for all gases at some distance from their points of liquefaction. It is nearly true for atmospheric air, nitrogen, oxygen, hydrogen, helium and a number of other gases at ordinary temperatures. According to Gay-Lussac's law, all gases have the same coefficient of expansion under constant pressure, and this coefficient also applies to change in pressure at constant volume. That is,

$$V = V_0 (1 + At)$$

and

$$P = P_0 (1 + At)$$

where P_0 and V_0 are the pressure and volume at zero centigrade, P and V are the pressure and volume at t centigrade and A is the coefficient. For the fahrenheit temperature scale,

$$V = V_{32} [1 + A_1 (t - 32)]$$

and

$$P = P_{32} [1 + A_1 (t - 32)]$$

where A_1 is equal to five-ninths of A for the centigrade temperature scale.

The laws of Boyle and of Gay-Lussac may be combined by assuming that a given mass of gas having pressure P and volume V at temperature t is compressed first isothermally to pressure P_0 and volume V_1 and then under constant pressure to volume V_0 at zero centigrade. Under these assumptions we have

$$PV = P_0 V_1 = P_0 V_0 (1 + At)$$

whence

$$\frac{PV}{t + \frac{1}{A}} = \frac{P_0 V_0}{\frac{1}{A}} = R$$

and

$$PV = R \left(t + \frac{1}{A}\right)$$

If A were a constant for all gases as stated by Gay-Lussac, then R would have the same value for all gases by taking equal volumes V_0 under the same pressure P_0 at zero centigrade. This is approximately true.

The Absolute Temperature Scale

Regnault found for the volumetric expansion of dry atmospheric air under atmospheric pressure from zero to 100 centigrade, that A = 0.003671. Hence, for dry atmospheric air,

$$PV = R (t + 272.4)$$

This relation indicates that if atmospheric air were cooled to a temperature t = —272.4 centigrade, either the pressure P or the volume V would be reduced to zero. This led to the idea of an absolute zero of temperature. For hydrogen, Regnault found A = 0.003661 whence $\frac{1}{A} = 273.1$. From these and other experiments on the expansion of various gases and their departures from the laws of a perfect gas, the absolute zero of temperature is now taken as —273.1 on the centigrade scale, equivalent to —459.6 on the fahrenheit scale. Temperatures on the absolute temperature scale are therefore found by adding 273.1 to the centigrade scale readings and 459.6 to the fahrenheit scale readings. Degrees centigrade absolute are sometimes called "degrees Kelvin".

Substituting the absolute temperature T for $\left(t + \frac{1}{A}\right)$ in the expressions for the combination of the laws of Boyle and Gay-Lussac, we have

$$\frac{PV}{T} = \frac{P_0 V_0}{T_0}$$

and

$$PV = RT$$

The latter is the equation of state for a perfect gas from which an actual gas deviates more or less depending upon its pressure and its temperature. The deviation is less the lower the pressure and the higher the temperature. Hydrogen is very nearly a perfect gas under pressures around atmospheric and for a wide range of temperature. This was the reason for its selection to define an international temperature scale. Atmospheric air differs but little from a perfect gas under moderate pressures at atmospheric temperature so that the above relations may be used in most engineering calculations involving the pressure, volume and temperature of atmospheric air.

References

For a more complete history and description of the mercury-in-glass thermometer, the reader is referred to the article entitled Thermometry in Glazebrook's Dictionary of Applied Physics. The articles on Thermocouples, Resistance Thermometers, Optical Pyrometers and Total Radiation Pyrometers

(Continued on page 40)

Problems *of the* Small Plant

By T. S. Jardine and W. Humphries

United Drug Company, Ltd., Toronto, Canada

So much has been said and written concerning the problems and practice of modern steam stations that it is diverting to consider the situation of the small plant operator who frequently has great difficulty in securing the required funds for necessary replacements of worn-out or obsolete equipment. This article relates the experiences of an operating engineer who, through his own resourcefulness and despite discouraging circumstances, was able to effect a substantial improvement in the operating economy of his plant, and increase capacity to meet a growing steam demand,—all at a very nominal outlay for equipment and labor.

THIS article is the history of a plant built in 1914 by a building contractor who did his own engineering.

Two horizontal return tubular boilers 16 ft. by 72 in. were installed and set as shown in Fig. 1. Grates were of the rocking type, 5 ft. 6 in. by 5 ft., set 3 ft. 6 in. from the bottom of the boiler. The bridge-wall was built up to 8 in. from the bottom of the boiler. Separate breechings were installed, running from the front of the boilers back to the stack behind. The stack, 78 ft. from the breeching to the top, was built in the middle of the building beside an elevator shaft and had four flues, as shown in Fig. 2. The idea was to provide for four boilers, although only three could be installed on the boiler room floor.

In 1918, when the load got heavier than could easily be carried with the setting as installed, several changes were made. Breechings were remodelled to enter the stack as shown in Fig. 3. Partition walls in the stack between 1 and 2 and between 3 and 4 were cut away for 15 ft. from the bottom and for 20 ft. down from the top of the stack. Then 12 ft. was added to the height of the stack, making it 90 ft. total height. With this arrangement more coal could be burned, but the smoke condition which had been bad before became worse. Neighbors were complaining, and the Smoke Inspector was threatening prosecution. Things went on until 1922 when staff changes were made and tests were begun to find out what actually was wrong.

The flue draft was .7 in. and the flue damper was run wide open all day long. Evaporation was low, roughly 4 to 5 lb. per lb. of coal as fired, and from 4 to 7 tons of ¾ lump coal was being burned in two shifts in Winter over a period of 15 hours. The old CO_2 meter was overhauled and gave the cheering news that 6 per cent was the best obtainable. It was plain that improvement could be made without spending more money, and the staff set out to do it.

The first change made was to instruct the fireman how to handle his flue damper and how to fire properly; he could not see it that way so eventually he was looking for another place where he could heat all outdoors. At the first opportunity, the bridge-wall was lowered so that the distance from the top of the wall to the boiler shell was increased from 8 in. to 24 in. This change prevented further burning of the boiler shell at the girth seam behind the bridge-wall but did not improve smoke conditions. Different low volatile coals were tried until finally the Smoke Inspector insisted that smokeless coal be used. This was stored in the coal bin in front of the boilers, at the end of the plant directly under the railway siding. During the Spring break-up, fire started in the bin; there was little room to handle it and the fire had to be drowned out with fire hose. That ended the use of smokeless coal, and the plant had to go back to as low volatile ¾ lump as could be bought.

The next step was to clear out the sloping fill in the combustion chamber down to the concrete floor 6 in. below boiler room floor level. The concrete floor was then covered with fire brick bats laid on edge, and sand was swept in to fill the cracks. This showed a little improvement, but not much. Then a combustion arch was built under the rear end of the boiler as shown in Fig. 4. The inside face of this wall, where it met the boiler, was corbelled out—the idea being to cause the gases to roll and thus insure better mixing. With careful firing this made some improvement, and CO_2 could at times be gotten up to 10 per cent. Under heavy loads there was still too much smoke, but by this time coal consumption was being lowered and a small approporiation was obtained.

A compound draft gage and a recording flue gas pyrometer were picked up second hand, overhauled and put to work. Furnace draft had to be .3 in. and stack draft .5 in. to keep steam up. Flue gas temperatures varied from 550 deg. fahr. to 650 deg. fahr. The steam load was steadily increasing so that one boiler, hand fired, could not carry Winter peak loads. To make things still more interesting, the Smoke Inspector lost patience and issued a summons to appear and show cause why smoke was being emitted for more than 6 minutes in any one hour. He had plenty of nice charts to prove his case and something had to be done. Cost figures were again obtained on stoker installations, but owing to some peculiar conditions of the tenure of the building, the management felt that the investment needed was greater than conditions warranted.

About this time, two 5 ft. by 5 ft. single retort underfeed stokers were offered for sale from a dis-

cont nu d plant. A bargain was driven and they were purchased on the ground, "as they stood," together with a belt driven forced draft fan, a Mason regulator and two Engineer Company's draft controls. These were all overhauled and refitted in the plant. Broken lugs on stoker frame castings were rebuilt by ox-welding new metal around carbon cores the size of the bolt holes required. The piston rods were found to be badly battered and the pistons were loose on the piston rods. New piston rods were fitted with a nut behind the head, and to gain clearance for this nut the cylinder head was bored and fitted with a 3 in. iron pipe plug. This repair has given no trouble since. Plain bearings in the fan were found in bad condition and were replaced by single row ball bearings.

These repairs being completed, the work of installing the equipment was started. The plant had to be kept in operation, so with No. 1 boiler on the line work was started on No. 2. The old boiler front was cut off as shown in Fig. 5, which shows the setting just after the windbox had been put in. The old grates and the bridge-wall were torn out and excavation started. For the windbox form, a pit was dug 4 ft. deep, 4 ft. wide and 8 ft. long sloping up to the front. Back from this pit a trench

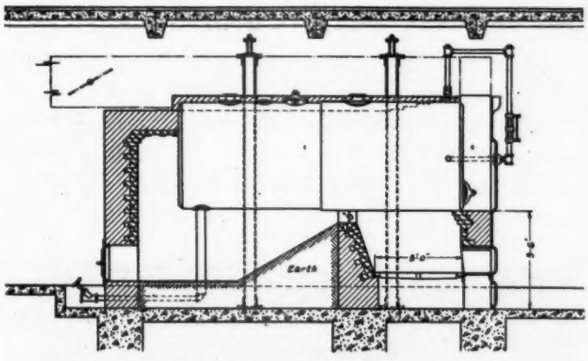


Fig. 1—Setting as originally installed

2 ft. wide and 2 ft. deep was dug to the rear wall and the rear wall broken through for the air duct.

Fig. 7 shows details of the installation. Because the footings of the building columns and of the boiler setting wall were almost in line, it was not possible to run the air duct in from the side behind the bridgewalls and air had to be brought in from the rear of the boilers. To add to expected troubles came an unexpected one. Footings under the rear wall, bridgewall and front arch were found to be of 2 ft. thick concrete, laid very rich in the wet clay, with a ¾ in. trap rock aggregate. This was so hard that electric drills made little impression on it. Pneumatic drills were not tried as the air pressure was too low and there was not enough of it. All this concrete had to be chipped out by hand in flakes. On cutting through the 4 in. concrete floor in the combustion chamber, a 6 in. layer of cinders was found and under that another 6 in. concrete floor. By this time the original contractor had failed and no one ever has been able to explain why the two floors. Under this lower floor the clay was dried out and about 20 deg. warmer than that of the clay under the floor away from the setting; this, although the furnace had been down over two weeks. Then the windbox core form was set and a 14 in. 24 gage galvanized pipe laid in on a concrete bed from the windbox through the rear wall. When this was concreted in, 10 in. had been gained in depth

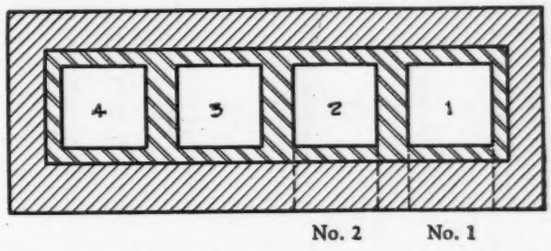


Fig. 2—Plan view showing original arrangement of stack flues and breechings

in the combustion chamber. To stop some of the heat leakage through the bottom, 2 layers of Silo-Cell No. 3 concrete, each 1½ in., were tamped in and covered with 2 in. of concrete topping. The 24 gage pipe served only as a form and dependence was placed on well spaded concrete for the air ducts when the pipe rusted out.

The stoker foundation was built to allow 4 ft. 6 in. from the side grates to the bottom of the boiler. This made necessary lowering the firing pit in front of the boilers 15 in. and the pit drain to the sump had to be lowered to drain the new level. Then the stoker was installed, the stoker front set up and the joint between the old and the new front spliced with a ½ by 3 in. mild steel bar bolted in place. Inside the joint a 3 in. by 3 in. by ½ in. angle was bolted to brace the joint and support the front arch. Furnace side walls were then built in, and at the grate, were corbelled 3 in. on each side to meet the 5 ft. by 3 ft. stoker frame. In the combustion chamber, the emergency opening to the windbox was covered by an 18 in. by 24 in. cast iron slab 1 in. thick laid in a 2 by

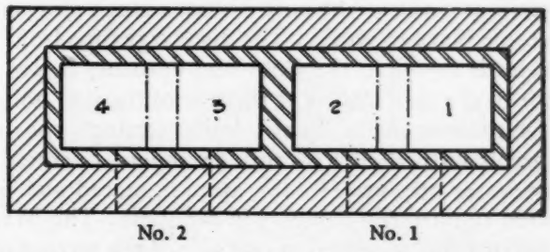


Fig. 3—Plan view of remodeled arrangement of stack flues and breechings

2 in. welded angle iron frame bedded in the concrete. The combustion chamber floor was again finished off with fire brick bats laid on edge and thin grout swept into the joints.

The bridge-wall was built up from the footing, 24 in. thick with solid fire brick, low grade in the core and back and high grade on the furnace side and top, to 18 in. above the top of the tuyeres. At each side wall above the bridge-wall, an angle wing wall was built out 8 in. up to the side of the boiler, as shown in Fig. 6. This was done to divert the flow of unmixed gases and air along the furnace side wall to

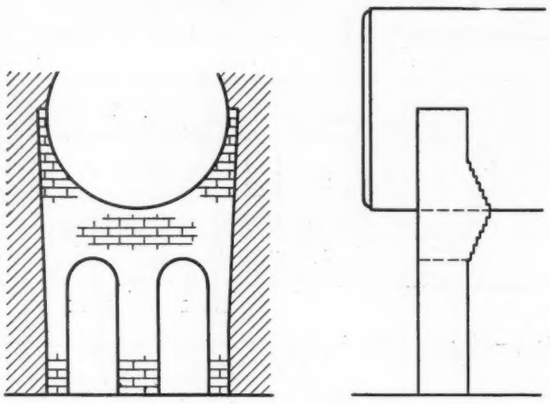


Fig. 4—Views showing arch arrangement as installed under rear end of boiler

the center of the combustion chamber. The idea actually worked but after the unit was in operation a while, heavy erosion of the side wall, above and in front of the bridge-wall, was discovered. During the next shut-down these wings were reduced to 6 in. projection and this seemed to give just as good results, but there was still too much erosion. The next time the unit is off the line this projection will be reduced to 3. in.

While the stoker was being installed and bricked in, the fan was installed on a platform mounted on two I beams laid between the stack wall and the rear end of the boiler setting, level with the top of the setting. The fan intake pipe was to run forward parallel with the I beams to a point about 3 ft. in from the rear end of the setting, ending in a bell mouth covered with coarse wire screen. Since the clearance between the top of the boiler and the ceiling is only 4 ft. 6 in., this takes hot air off the ceiling to the furnace and gives about 30 deg. to 60 deg. superheat, as well as making the boiler room a much more comfortable place to work. The discharge pipe from the fan leads down to the floor and branches under the floor to the air dampers at the rear of the two boilers.

On the rear end of the two boiler settings, the draft controls with their hydraulic cylinders, operated by city water pressure—80 lb., were mounted and connected to butterfly dampers in air ducts. The Mason regulator was mounted at one side of the setting near the front, and the steam pressure line taken from one end of the header. Because high pressure steam was drawn irregularly from both ends of this header, there were sudden pressure variations at the regulator, and this control line had to be moved to a point on the header midway between the two boilers where the pressure was better equalized. A 1½ in. iron pipe rock shaft was installed at the front top corner of the setting and to this were clamped sector arms connecting to the two dampers in the breeching, the air damper in the fan casing and the two stoker regulating valves.

After the stokers were started it was found that stack draft was so high, around .5 in. to .7 in. that the breeching damper could not properly control it. Auxiliary dampers, hand operated by pull chain, were installed in the breechings at the rear of the boiler. These are adjusted daily as needed to give .1 in. furnace draft with full load.

After No. 1 setting was finished and dried out, this boiler was put on the line and work was started on No. 2. It took less time as all the control work was already done, and less time was lost on the excavation work.

No serious trouble has been experienced in the operation of these stokers since they were installed. At first there was a little trouble with the stoker operating valves, but this was completely cured by a combination packing, consisting of metallic rings and asbestos sheet rings alternated.

Some early trouble was also experienced in getting good distribution of coal from front to back; this was found to be due to the pusher blocks being too low and too near the front of the furnace. A pattern was made and blocks were cast in 2 per cent nickel iron mixture. This was easy to drill, and after four years' use they appear to be good for at least two years more. No trouble has been experienced with burnt tuyeres; 15 in. to 18 in. of coal is always carried over the tuyeres and the butterfly dampers in the air ducts are blocked so that they cannot com-

Fig. 5—View of boilers showing preparations for installation of first stoker

pletely close. This causes a lower CO_2 at minimum loads because of excess air, but it saves the tuyeres and grates,

Considerable study has been given to getting better efficiency on light loads and experimental work has

been carried on for the past two years. It is intended to alter the position of the rocker arm sector which is pulled over by the Mason regulator cable. As installed, it directly translated straight line motion of the regulator to equivalent rotary motion of the rocker arm. This motion is transmitted to a sector arm on the shaft of the butterfly damper in the breeching. Due to the varying opening of the damper with equal movement of the sector operating it, regulation is very abrupt on low loads and difficult to control. It is intended to offset the rocker arm sector connected to the regulator so that direct line motion of the regulator will be translated to a 1:2:4 ratio of rocker shaft movement. This should iron out the difficulty to a considerable degree, although not so completely as if a fully compensated regulator could be installed.

To sum up, the whole installation of stokers and instruments was made by the regular operating staff and maintenance labor has cost less than $5000. In the past 4 years, instead of low volatile ¾ lump coal, costing laid down an average of $5.70 per ton, it has been possible to burn a high volatile Youghiogheny ¾ in. nut and slack costing an average of $5.00 per ton laid down. The reduction in consumption, even with a load now double that of 1922, and the reduction in cost per ton, has saved in round numbers $10,000. This is a fairly good argument for reasonably up to date betterment. All minor changes and experimental work were absorbed in monthly expenses and year by year the total operating expense has been reduced below that of the previous year.

Present average operating conditions under full load are as follows:—

Furnace draft—.1 in.; stack draft—3. in.; flue gas temperature—450 deg. to 500 deg. fahr.; CO_2—10 to 14 per cent; steam pressure—100 lb. Lacking flow meters to record the steam consumption, it is not possible to give an exact evaporation figure but it is between 8 and 10 lb. average. This is largely due to all condensate going back to the boiler at 200 deg. fahr. Only about 5,000 gal. of raw water make-up is used daily. This make-up is treated with boiler compound, about 1½ qt. per day. It is now possible to carry about 150 per cent of boiler rating at full load and to force output up to 200 per cent for short peaks. However, above 150 per cent rating, CO_2 falls off, flue gas temperature rises and efficiency falls off rapidly. Furnace walls laid with Ohio brick stand up well, giving from 10 to 15 months service. This installation appears to work best with a semi-coking ¾ nut and slack coal, 30 to 34 per cent volatile with from .5 to 1.25 in. air pressure in the windbox. The fire under full load is a clear white and the combustion chamber viewed from the back glows a bright cherry red. Runs of 4 hr. have been made with no smoke visible at the stack, and all day runs with only a slight gray haze visible at times.

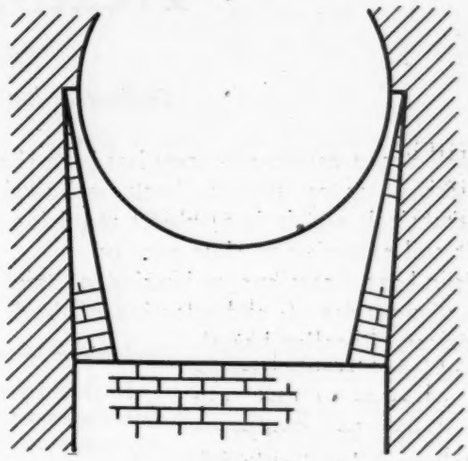


Fig. 6—Wing wall arrangement installed to direct flow of gases

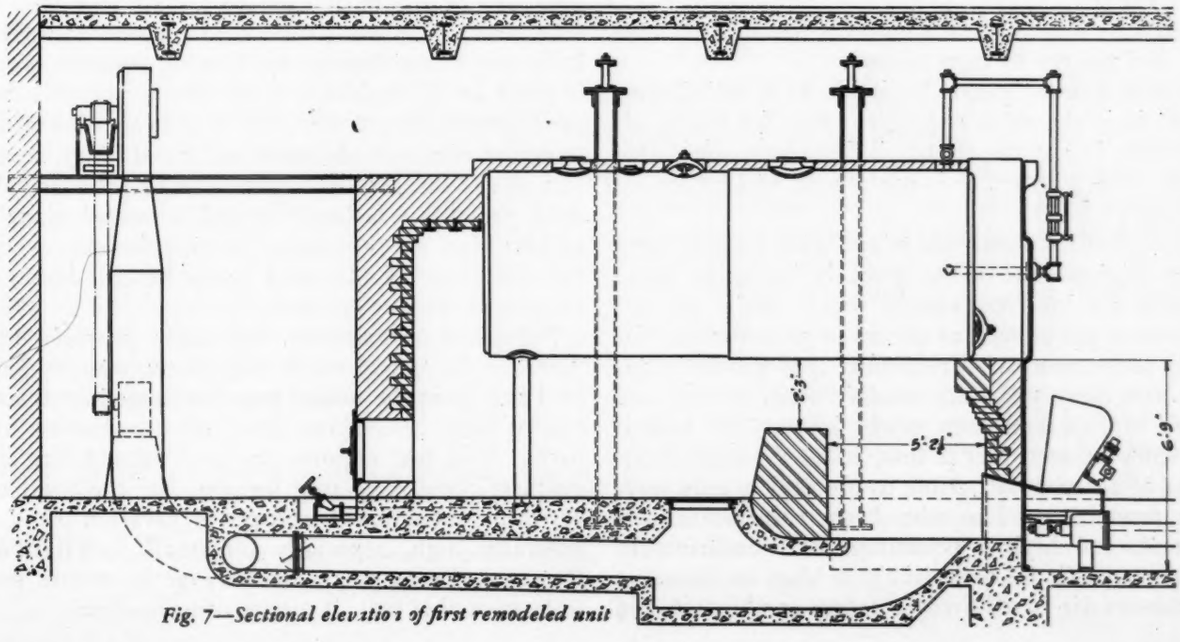


Fig. 7—Sectional elevation of first remodeled unit

Fuels *and* Furnaces *in* Heat Treatment *of* Steel

By W. O. Renkin
Combustion Engineering Corporation, New York

THE heat treatment of steel has been the subject of many papers, both technical and practical, and it is a subject requiring more thought and attention as time goes on.

Efficient heat treatment or heating of steel calls for the efficient use of, and selection of, both fuels and furnaces. Locality has always had considerable bearing on the selection of fuel, and furnace design has frequently been selected by "rule-of-thumb;" in fact there is very little accurate data available on this subject.

Vast strides have been made in the last decade, and today we are beginning to make use of the engineering knowledge gained by practical experience, so that it is high time for furnace design and fuel selection to be more carefully considered.

In recent years the iron and steel industry has shown an increasing tendency to effect economies in the utilization of fuel both for power generation and for the many heating processes of the industry. The great variety of furnaces and types of fuel available has complicated the problem and has made it difficult for operating engineers to ascertain the most successful and economical methods of firing. This article contains the complete text of a paper on this subject presented before the Association of Iron & Steel Electrical Engineers at Philadelphia, January 29, 1930. The author contends that the cost of refractory maintenance, now the subject of considerable investigation by steel plant engineers, could be greatly reduced through the use of dry coke fines in gas producers as these fines permit a gas devoid of the illuminants which are so generally destructive of refractories.

Fuels

There is a wider variety of fuels available today than ever before, and they should all be given careful consideration from the standpoint of:

First—Their effectiveness in giving the correct type of flame required by the particular operation and,

Second—The cost of the fuels known to be suitable fuel per ton of steel treated.

Where natural gas is available at a satisfactory price, it is the most convenient fuel for nearly all purposes, but as the supply is frequently unreliable in the cold weather, it is not a good fuel to depend on solely.

Blast furnace waste gas mixed with producer and other higher heat value gases is becoming quite popular for low temperature work, while oil and coke oven gas as well as tar are in great demand for high temperatures. Bituminous coal producer gas has been very generally used in open hearth and other high temperature work, but as the overall efficiency of such fuel is low, it would seem somewhat of an economic crime to use coal in this way. This producer gas like other high temperature fuels contains too high a percentage of illuminants in the form of $C_2 H_4$ (ethylene), so that an excessive amount of air is required to secure combustion and prevent excessive damage to furnace brickwork.

According to a paper presented by F. H. Leahy before the Twenty-fifth Annual Meeting of the Association of Iron and Steel Electrical Engineers in Pittsburgh last year, the gas that best suited the needs of his plants contained 0.70 per cent illuminants, and according to the records of other authorities, good producer gas was found to contain from 0.60 per cent to 0.90 per cent of $C_2 H_4$. Experience has shown that only from 2.8 to 3 per cent of the heat units in the gas need be illuminants for the open hearth furnace and for heating furnaces practically no illuminants content is required.

The use of by-product coke oven gas has had a very rapid growth, and although the installation cost is large, this fuel is being used very extensively, both alone and mixed with other gases. If this gas has been passed through a benzol plant, it forms a most adaptable fuel, as the illuminants required, or needed, can be so readily added in the form of tar or oil by parallel firing at the furnace itself. This fuel, however, is not the most efficient for all purposes, as when it has not been passed through a benzol plant, it is very unsatisfactory for heating furnaces, since it gives an illumninated flame which not only has small penetrating power, but which also has a destructive effect on the steel and causes high metal loss in the furnace. However, the by-product coke oven gas that has been through a benzol plant is an ideal fuel for continuous heating furnaces where the thickness of the steel being heated does not vary more than 15 per cent.

Pulverized bituminous coal when properly prepared is the most satisfactory direct way to burn coal and gives the widest possible range in and control of flame conditions, especially for heating furnaces. This fuel requires the least expenditure and simplest type of heating furnace, but the total investment, including the proper preparation plant, is generally high, especially for small installations. However, owing to the wide range in control possible with this fuel, it merits consideration.

For some time past, we have been gathering data on the use of coke fines instead of expensive bituminous coal in gas producers. As most by-product coke is cooled by the wet quenching process, the use of coke fines has not been very successful, and it has taken considerable time to find the reason. Wet quenched coke fines screened through a 1-in. screen and over a 5/8-in. screen can be used in gas

Fig. 1—Typical plant for dry quenching of coke. This plant produces approximately 1000 lb. of steam per ton of coke quenched

producers, but it requires more attention than coal and therefore has not become popular. However, with dry quenched coke fines very successful operation is being secured on coke through a 7/8-in. and over a 3/16-in. screen.

Producer gas made from dry quenched coke fines should prove ideal for heating furnaces as owing to its lack of C_2 H_4, it gives mellow semi-luminous flame in its best form. This gas should also prove highly efficient for open hearth furnaces, as it permits the controllable addition of the needed illuminants directly at the furnace either as tar or oil. By adding the illuminants as C_2 H_4 at the furnace, a better regulation of flame is assured and a more efficient furnace operation can be expected.

In one plant using dry quenched coke fines with a heating value of 12,200 B.t.u. per lb. and having the following analysis,

Volatile	2.80 per cent	
Fixed Carbon	83.40 per cent	
Ash	13.80 per cent	
Sulphur	0.73 per cent	separately determined.

Producer gas was secured with a heating value of 134 B.t.u. per cu. ft. and with the following analysis:

CO_2	6.30 per cent
O_2	0.10 per cent
CO	26.40 per cent
H_2	12.60 per cent
CH_4	0.70 per cent
N_2	53.90 per cent

The gas produced from each pound of coke contained —10,334 B.t.u.

A comparison of the heat in gas produced from bituminous coal and from dry quenched coke fines shows:*

Assuming coal at	14,100 B.t.u.
Heat in gas going to furnace per net ton of coal charged to producers	19,740,000 B.t.u.
Heat in gas going to furnace per net ton of dry coke fines charged to producers	20,668,000 B.t.u.

The reduction in cost of gas going to furnace per million B.t.u. is as follows:

Assume bituminous coal at	$3.00 per net ton
Gasification charge	60 cents per net ton
Total cost per million B.t.u. in gas going to furnace	18.2 cents
As the coke fines have very little value from wet quenched coke, we are conservative in assuming a value of	$2.00 per net ton
Gasification charge	60 cents
Total cost per million B.t.u.	12.5 cents
Reduction in cost of gas going to furnace per million B.t.u.	5.7 cents
Or a saving of approximately	31 per cent

Furnaces

Furnace design has so frequently been a compromise between theory and practice, that it is very difficult to offer many suggestions, but the following facts will no doubt be of interest.

The different fuels require generally different furnace design.

Furnaces using natural gas require very small combustion chambers, and regenerative type furnaces require only checker chambers for preheating the air which means a fairly simple construction. Recuperators give very good results with this fuel.

Using blast furnace waste gas enriched with other gases requires furnaces of special design, with larger volume owing to the larger volume of inerts contained in these gases. Very little information is

* Note: During the year 1929, by-product coke production amounted to 51,475,481 tons. If this had been dry quenched, the fines, amounting to approximately 5,500,000 tons, would have been available for use in gas producers in connection with open hearth and heating furnaces. This tonnage of fines would have replaced about 5,750,000 tons of high priced bituminous coal and the saving in fuel cost per ton of steel would have been approximately 31 per cent, representing a money saving of over $8,000,000.

available as to furnace operation using such combination fuels.

Bituminous coal, producer gas fired furnaces have been so standard and so highly developed that it is surprising no greater efficiency has been secured even

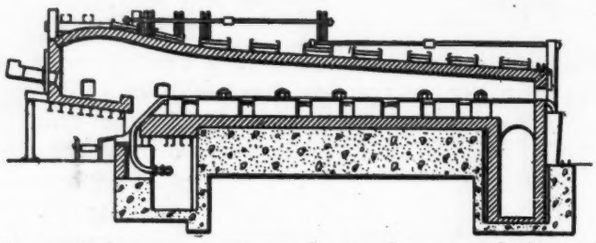


Fig. 2—Modern type continuous heating furnace with flat roof. This furnace is correctly proportioned to secure proper heating of steel and effective use of the entire furnace length

though the gas producers have been greatly improved. This fuel does not lend itself at all well to non-regenerative type furnaces, and the gas actually going to the furnace rarely contains more than 70 per cent of the B.t.u. in the coal charged to the producer.

Furnaces to successfully burn this fuel are expensive in first cost, as well as upkeep, requiring as they do double regenerator chambers and reversing valves.

Oil and tar are both satisfactory fuels, but in general are found to be more expensive than the other fuels. Furnaces to give best results should be of the regenerative type so as to properly preheat combustion air. They need only be of the single checker chamber type, however, as only the air is preheated.

With producer gas coal at $3.00 per net ton de-

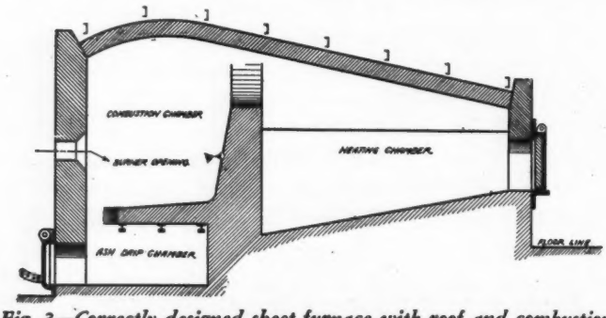


Fig. 3—Correctly designed sheet furnace with roof and combustion chamber designed to provide the low temperature needed in the sheet chamber and at the same time give the heater control of flame at all times

livered at open hearth plant, a maximum price of 3⅓ cents per gallon can be allowed for tar or oil to have equivalent fuel cost per ton of steel produced.

By-product coke oven gas fired furnaces have proven as a rule very efficient. However, this fuel requires a low furnace roof as it is necessary to press the gas down on to the steel. In heating furnaces of the continuous type, this fuel requires a fairly high velocity and with gas that has been through the benzol plant, records have been secured as low as 2,700 cu. ft. of 450 B.t.u. gas per gross ton of steel heated, while with gas that has not been through the benzol plant, fuel consumptions of 7,000 cu. ft. for very unsatisfactory heating have been recorded.

Pulverized bituminous coal fired furnaces require larger combustion chambers and furnace volumes. For heating furnaces, the most satisfactory velocity of the fuel is approximately 4,000 ft. per minute, while for open hearth furnaces, the velocity must be adjusted so as to carry the actual flame beyond the center of the furnaces. This requires approximately a velocity of 8,000 feet per minute. With properly prepared coal and furnaces of correct design, the widest range of control can be secured with this fuel.

One of the principal advantages of pulverized coal is the ability to use coals that are not suitable for use in other forms.

In designing heating furnaces for use with pulverized coal, a combustion chamber length of approximately 8 ft. 6 in. is required, and the heat liberation per cubic foot of combustion space between the inside of burner wall and the furnace side of the bridge wall should not exceed 50,000 B.t.u. per hour. The flame velocity over the bridge wall should be approximately 15 ft. per second, and the gas velocity leaving the furnace should not exceed 25 ft. per second.

Dry quenched coke fines producer gas should prove a very satisfactory fuel for many plants, especially those at present using bituminous coal producers.

Producer gas made from dry coke fines can be used in existing regenerative type furnaces with a minimum of alterations; in fact at the present time, we believe the dry coke fines can be substituted for the more expensive bituminous coal without any change in equipment.

Substituting dry coke fines for bituminous gas coal permits the use of 4½ per cent less fuel, and as the coke fines are so much cheaper than bituminous coal, the actual reduction in fuel cost per million B.t.u. works out, in some cases, to as much as 40 per cent.

TEMPERATURE SCALES

(Continued from page 33)

discuss more thoroughly than the present article, the characteristics of these temperature measuring devices. The article on Realization of Absolute Scale of Temperature will also be found of interest although it antedates the international adoption of such a scale as defined in the article entitled The International Temperature Scale by G. K. Burgess in Bureau of Standards Journal of Research for October, 1928. Two other articles by the present author may also be of interest, namely, How to Use Mercury-in-Glass Thermometers, Power, March 20, 1923, and Exposed Stem Correction for Mercury Thermometers, Power, February 27, 1923.

Sulphur Fumes *in* Stack Gases

A Valuable Interim Report in Great Britain on the Latest Power Station Problem.

By David Brownlie

In a previous article, the author dealt with the question of sulphuric acid (SO_3) and sulphurous acid (SO_2) in stack gases, and the damage to the surrounding neighborhood resulting from the emission of these acids from the stacks of large power stations. Details were given concerning the litigation between the Manchester Corporation and the Farmers' Federation with respect to Barton Power Station, and reference was made to the agitation over the new Battersea Power Station now being erected in London. Particular emphasis was laid on the fact that this subject can now be regarded as a problem that power station authorities in more or less all countries will have to solve.

An article by Mr. Brownlie on the subject of sulphur gas fumes from power station stacks was published in COMBUSTION several months ago. In the present article the author discusses an important report on this question which has recently been issued under the auspices of the British government. This report presents comprehensive data on the results secured in large scale experimental work involving the washing of flue gases to remove the objectionable sulphuric and sulphurous acids. Drawings and recommendations are included in the report covering a proposed installation for the Battersea Power Station which has been the storm center in the controversy over this subject in Great Britain.

In this connection, there has just now appeared in Great Britain a highly interesting publication entitled "Treatment of Sulphur Fumes in Connection with the Working of the Proposed Electric Power Station of the London Power Company at Battersea." This is in reality an Interim Report of Dr. E. Ardern of Manchester and Professor R. V. Wheeler of Sheffield University, who have been advising the London Power Company, the owners of Battersea Power Station, with regard to the best methods to adopt in order to prevent any possible damage to the surrounding neighborhood due to sulphur in the stack gases. There has also been published by a government committee a short comment on this report.

The report gives in detail the results of large-scale experiments carried out between April and August of 1929 at the Grove Road Power Station of the London Power Company in connection with the washing of stack gases by means of water sprays so as to scrub out the sulphur gases before discharge from the stack; this work followed earlier laboratory experiments undertaken at the St. Pancras Electricity Station, London.

The washing of combustion gases with water is, of course, not a new idea; in fact, this method has actually been carried out for many years at Rowntree's chocolate factory in York, although the principal object in this case was to get rid of every trace of smoke.

Obviously, the main considerations are the net capital cost of the plant required for this purpose, the power necessary for the circulating pumps supplying the wash water in the form of sprays, and the methods to be used in dealing with the acid water resulting.

Nothing is said in the report about the capital and operating costs, a most unfortunate omission. However, the results of the experiments are given in detail and the opinion is expressed that the water of the Thames River is already sufficiently alkaline to neutralize all the acid extracted from the stack gases by mixing the dilute solution with the condenser water before discharge to the river.

The method of handling the acid water may, in many instances, represent a serious problem.

For example, we are informed that the Battersea Power Station, when completed, will burn 2000 tons of coal per 24 hr. If we take the average figure for the sulphur in the coal as 1.5 per cent, this, on complete combustion, would represent 90 tons calculated as sulphuric acid (H_2SO_4), and naturally it would be undesirable to discharge this amount of acid daily into most rivers.

The present section of Battersea will have three boilers, which altogether will burn 60 tons of coal per hour at normal full load during the day; on this basis, it is stated that each boiler will discharge 170,000 cu. ft. of flue gas per minute, or 510,000 cu. ft. of flue gas per minute for the three boilers, equivalent therefore to the combustion of 1 ton of coal.

Assuming the coal to have an average of 1.5 per cent sulphur, it is calculated that with the consumption of 1 ton of coal and the production of 510,000 cu. ft. of flue gas per minute, the latter would contain, as discharged normally from the chimney, 0.03 per cent SO_2 and 0.05 per cent SO_3. The preliminary laboratory experiments at St. Pancras show, theoretically, that to take out 255 cu. ft. of SO_3 from 510,000 cu. ft. of flue gas per minute would require 17,300 gal. or 77.25 tons of cold water per minute in the form of forced sprays with a reasonable time factor of contact, certainly not more than 12 seconds; these figures are based upon a water temperature of 68 deg. fahr.

A hitherto unknown circumstance with regard to sulphur in flue gases is the relative proportions of

sulphuric acid (SO_3) and sulphurous acid (SO_2), a matter of great practical importance since SO_3 is much more soluble in water than SO_2. According to Ardern and Wheeler there are, under normal conditions, about 60 per cent SO_2 and 40 per cent SO_3, although further research work on this point is desirable, as the report points out, and, of course, the proportion may vary considerably depending upon individual conditions.

With regard to the less soluble SO_2, the removal of 153 cu. ft. of this gas from 510,000 cu. ft. of flue gas per minute would require 79,400 gal. or 354.5 tons of cold water per minute.

For the experimental work at Grove Road Power Station there was erected the plant illustrated in Fig. 1, which consists of a cylindrical absorption tower 27 ft. high and 3 ft. 6 in. diameter provided with three groups of 40 nozzles each for the wash water, situated at the respective heights of 10, 17 and 24 ft. above the ground and supplied by a force pump. In most of the experiments, the portion of the tower between the two upper groups of sprays was filled with absorption rings of the usual character. The flue gases, entering at the bottom through a 12 in. pipe from the stack, passed up the tower and were thoroughly scrubbed and washed by the water sprays.

During these experiments, two different coals were burned in the power station boilers which are at the opposite end of the scale as regards sulphur, that is Northumberland Rough Smalls which contain on the average of from 3.63 to 3.90 per cent total sulphur—a very high figure and Scotch Washed Peas, varying from 0.99 per cent to 1.23 per cent sulphur. The water used entered the cylindrical tower at 66 deg. fahr., and was discharged at an average temperature of about 85 deg. fahr.

The report gives the exact results obtained under many different conditions as regards the amount of water and velocity of the gas passing up the scrubber. With a cold water flow of 1900 gal. per hr., the data show that 100 per cent of the sulphur was removed by using from 45 to 58 tons of water per ton of coal burnt in the boilers, whereas cold water equivalent to say from 26 to 29 tons per ton of coal burnt removed only from 59 to 78 per cent of the sulphur. Under these general conditions, when sufficient water was used to remove all of the sulphur, there was a time factor of over 12 seconds.

One of the interesting observations made was that

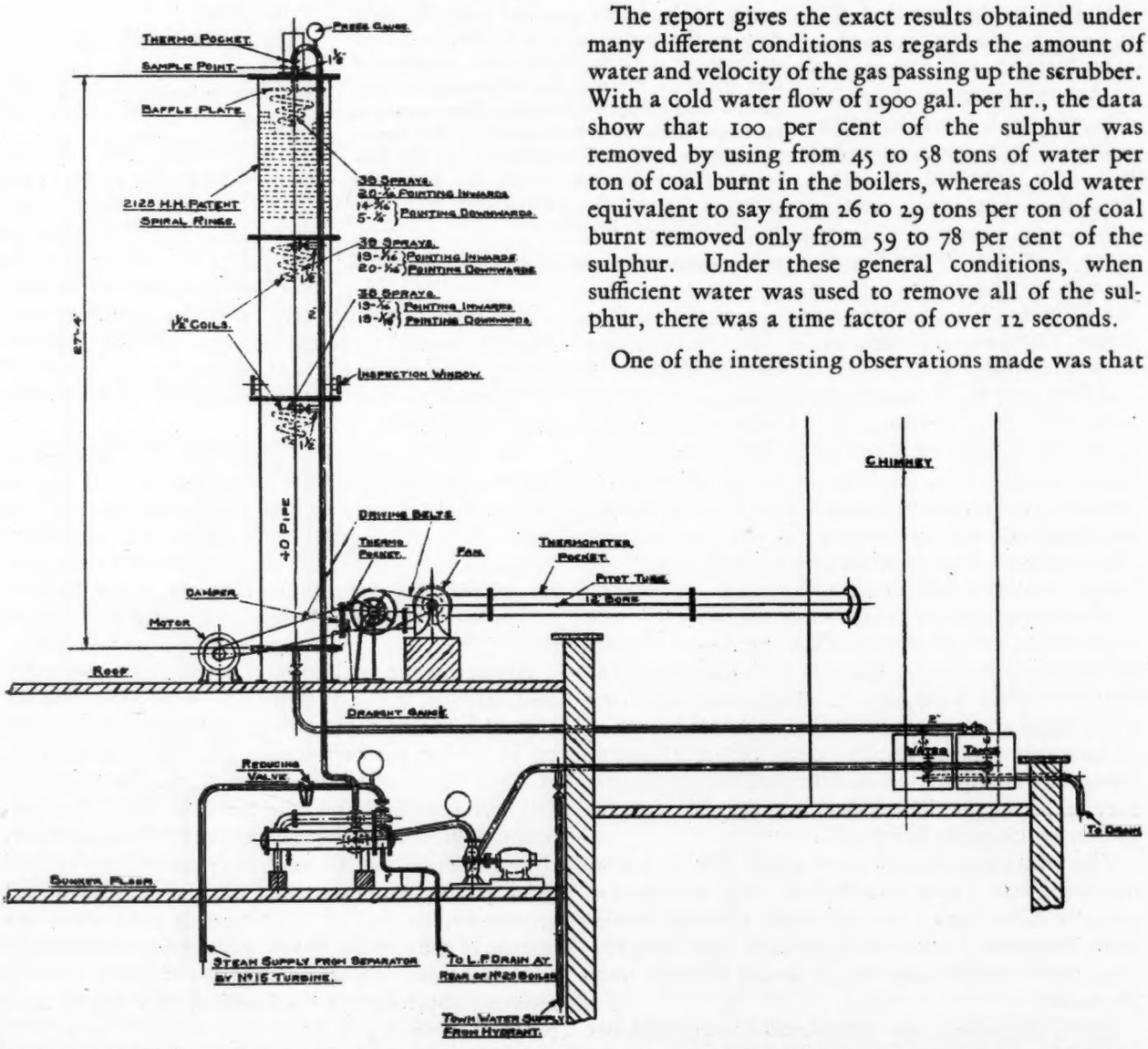


Fig. 1—Experimental plant operated at the Grove Road Power Station, London, for the removal of sulphur products from stack gases by washing with water sprays

warm water increased considerably the efficiency of the absorption; in other words, if the temperature of the water was increased, much less water was required. At first thought this seems almost incredible, since warm water naturally will absorb less gas than cold water, but the explanation seems to be that at a slightly increased temperature, such as, for example, 145 deg. fahr., the greater part of the sulphurous acid (SO_2) is oxidized to sulphuric acid (SO_3), and since the latter is much more soluble in warm water, the efficiency of the gas absorption is increased despite the rise in temperature of the water. Thus, taking the wash water at 145 deg. fahr., with the temperature of the flue gas entering the tower at 190 deg. fahr. and leaving at 140 deg. fahr., it is possible that a much smaller quantity of water will wash out say 96 per cent of the total sulphur. Under these conditions 17 to 21 tons of water per ton of coal burnt would be sufficient even with a high sulphur coal. If an abnormally good coal, as regards sulphur content, is used, then it is possible for as little as 6 tons of water per ton of coal to take out 90 per cent of the sulphur, with a flue gas velocity of 3.2 ft. per sec.

Why SO_2 should be oxidized to SO_3 in this manner is a mystery, but there is no question about it as there is hardly any smell of SO_2 in the wash water, a condition that is very different when cold water is used. It is suggested that this may be due to catalytic action or the formation of ozone or hydrogen peroxide during the evaporation of the hot water, caused by the flow of the gases.

Fig. 2 shows one of the curves from the report which indicates the relation between the percentage of sulphur elimination and the amount of water used by the scrubber in gallons per hour, in each case taking hot and cold water. Thus, for example, at about 1500 gal. per hr. with hot water there is 95 per cent of the sulphur absorbed, whereas with cold water the figure is about 78 per cent, in all cases the time factor being from 14 to 50 seconds.

The report contains a detailed drawing showing the installation suggested for Battersea Power Station comprising a series of washer towers at the stack base, each containing three groups of water sprays with packing in the form of roughly sawn boards, in place of ordinary packing rings, to increase the contact between the gases and water. In connection with this suggested installation, it is stated that the amount of water required, which, although it is not very clearly indicated, may be as low as 12 tons of water per ton of coal, would be only about a fortieth part of that of the condenser water from the turbines, and that this acid water can be mixed with the condenser water, as already mentioned, before discharge to the River Thames.

The Thames is said to contain approximately 17 to 20 parts per 100,000 as $CaCO_3$, that is, being slightly alkaline, while with hot water, the average acid water from the scrubbers at the Grove Road experimental plant contained 0.029 H_2SO_4, that is, 29 parts per 100,000. Consequently, if one volume of this very dilute acid is mixed with 40 volumes of the Thames water, according to the above figures, then the final mixture has 15.80 parts alkalinity as $CaCO_3$, so that there should be ample margin.

Apart from the probably high capital and operating costs involved in this project, there may be difficulty in mixing effectively such huge volumes of water. Furthermore, it is not absolutely clear that

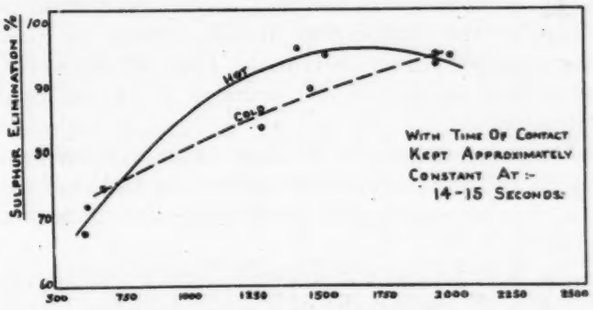


Fig. 2—Curves showing the relation between the percentage of sulphur elimination from stack gases and the amount of water used in the scrubber in gallons per hour, both hot and cold

the Thames is always so alkaline, and presumably it varies in this respect from year to year. A new problem is also likely to arise if every power station on the Thames, including Chelsea and Barking, for example, is compelled to wash the whole of its flue gases and likewise discharge sulphuric acid to the river. However, even in this event, it would probably be a practical proposition to finish off the washing with say lime water. The crux of the whole matter is the total net cost and whether the community is prepared to pay for this in terms of increased price of electricity. The total benefits resulting, however, will probably be well worth any reasonable expense.

No mention is made in the report of another important possibility, that is, the total gasification of the coal, complete purification of the relatively small amount of gas, say 120,000 cu. ft. per ton of coal, and then combustion of this gas in the boilers, so that there would be no need to treat the huge volume discharged from the chimney, which would consist of nothing but nitrogen, CO_2, and perhaps a mere trace of perfectly harmless unburnt products, chiefly CO, along, of course, with oxygen from the excess air used in the furnace.

Present developments, however, seem to indicate that the time is approaching when at least the larger stations will find it practicable to wash their stack gases. The adoption of this practice, in conjunction with the use of dust collectors, would appear to be a final solution to the problems of dust, dirt, smoke and objectionable acid emissions from power station stacks.

How *to* Determine *the* Conditions *for the* Most Economical Boiler Operation

By B. J. Cross

Combustion Engineering Corporation, New York

THE preceding articles of this series have dealt with the methods of determining the various losses incident to the generation of steam by the combustion of fuel. None of these losses can be entirely prevented. They can, however, by careful operation, be reduced to a practical minimum.

The most important of these losses are the heat lost in the dry products of combustion and the heat lost due to incomplete combustion and unburned carbon.

The heat lost in the dry products of combustion varies with the weight of gases discharged to the stack and also with the stack temperature. The larger the weight, or volume, of the gases passing through the boiler, the higher will be their exit temperature. This loss, therefore, mounts rapidly as the amount of excess air is increased. Obviously it is an advantage to keep the percentage of excess air low. Just how low the percentage of excess air can be kept depends upon the loss due to incomplete combustion.

The amounts of unburned carbon in the refuse and partially burned carbon appearing as carbon monoxide in the flue gases increase with a decrease in air supply, the rate of burning being constant. As we thus have one loss that increases with the amount of excess air supplied and another loss that increases as the air supply is reduced, a compromise must be made and the air supply adjusted so that the total loss will be at a minimum.

The loss due to moisture in the flue gases will change but little with changes in the amount of excess air and with change in rating. The amount of moisture per pound of fuel is practically constant. The loss will increase slightly with increase in flue gas temperature.

The heat lost by radiation will be practically constant at any given rating, providing the setting is operated under slight draft. The absolute loss of heat by radiation will also be practically constant for any rating. The per cent loss will, of course, vary with the rating, as it is expressed in per cent of the fuel burned.

For any given equipment the losses must be determined by actual test. A series of tests should be made at each of several ratings. For each rating, the per cent of excess air should be varied. From the data so obtained it will be possible to plot curves showing how the different losses vary with excess air and to plot the curve for total losses. Losses such as that due to radiation, which is constant, and that due to water vapor in the flue gas, which is practically constant, need not be considered. An inspection of this curve will show the best amount of air for most efficient operation at that particular rating.

Typical loss curves as plotted against excess air supplied are shown in the upper chart. The rating is assumed constant. It may be seen that in this particular case, the total losses are lowest at about 35 per cent excess air. The curve for total losses shows that these losses increase more rapidly when the air supply is reduced below 35 per cent excess than when the air supply is increased beyond this point. It would be better, therefore, if the boiler operator is to be allowed a margin for operation, to set the operating point slightly above 35 per cent excess air rather than below.

Excess air-losses curves are also useful in comparing the adaptability of different fuels to particular burning equipment. Usually the fuel that permits operation with the lowest excess air is the best suited to the equipment. Economy, however, rather than efficiency is the criterion. A fuel that permits 4 per cent higher efficiency yet costs 10 per cent more is poor economy.

When the best amount of excess air has been determined, the test results may then be plotted to show the variation of the losses as the rating is increased. The losses plotted at each rating should be those corresponding to the best air supply for that rating.

The lower chart shows typical loss curves as plotted against rating. The curve of total losses shows that the point of most efficient operation is at very low rating. We do not of course have the same choice as to rating as we do in the matter of excess air. The boiler rating is usually regulated by the plant load. This curve, however, indicates the cost of the increment in steam obtained as the rating is increased. Thus, from the curves of the lower chart it may be seen that at 200 per cent rating, the total losses are 20.5 per cent. If the rating is increased to 300 per cent the losses are 24.5 per cent The efficiency is decreased by 4.0 per cent and the fuel cost of a unit of steam is increased. This increased cost of steam should be balanced against the investment costs of a new unit in order to determine whether or not it is more economical to add a new boiler and operate at 200 per cent rating or operate the existing units at 300 per cent rating.

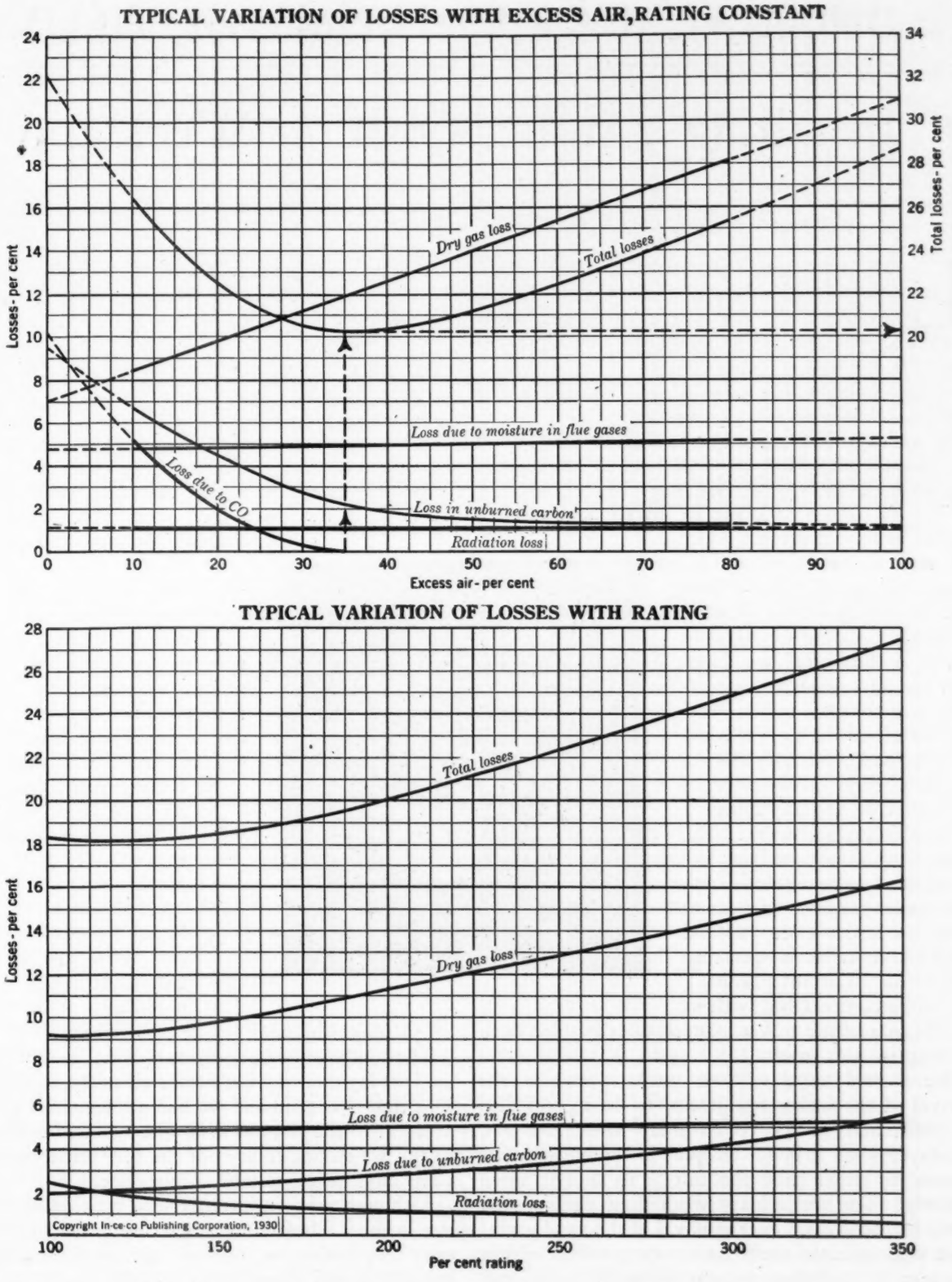

TYPICAL VARIATION OF LOSSES WITH EXCESS AIR, RATING CONSTANT
Losses - per cent
Total losses - per cent
Excess air - per cent
Dry gas loss
Total losses
Loss due to moisture in flue gases
Loss due to CO
Loss in unburned carbon
Radiation loss
TYPICAL VARIATION OF LOSSES WITH RATING
Losses - per cent
Per cent rating
Total losses
Dry gas loss
Loss due to moisture in flue gases
Loss due to unburned carbon
Radiation loss
Copyright In-ce-co Publishing Corporation, 1930

CHART FOR DETERMINING THE CONDITIONS FOR THE MOST ECONOMICAL BOILER OPERATION

No. 8 of a series of charts for the graphical solution of steam plant problems

UNUSUAL STORIES FROM THE FIELD

Installing *a* Stoker Over *the* Week-end

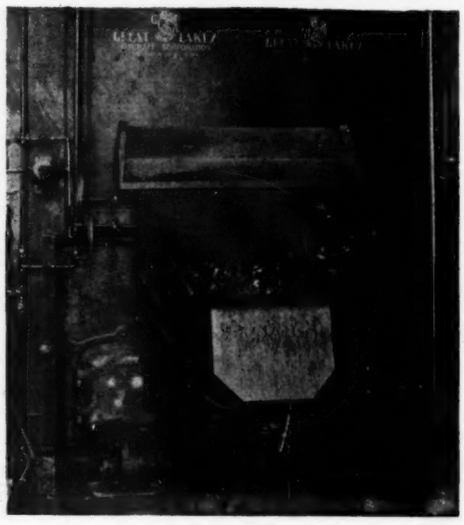
By Merl J. Chapman

Mechanical Superintendent, The Great Lakes Aircraft Corporation, Cleveland, Ohio

LATE last Summer, it became evident that it would be necessary to increase the capacity of our boiler plant in order to provide steam for heating an addition to our factory buildings. At that time our plant consisted of one hand fired, 236 hp. boiler which supplied all the steam we required for heating and process work.

In addition to increasing capacity, we also had in mind the elimination of smoke and improving the economy of our boiler operation.

The decision was made to install an underfeed stoker under our present boiler to replace hand-fired grates, but since we would be into the beginning of the heating season before the material could arrive on the ground, we placed our contract with the understanding that the boiler could be out of service for the work of changing over only during a period from Friday noon of one week to Tuesday morning of the following week. The stoker manufacturer was responsible for the whole job and was under contract with us to take the boiler as it was and turn it over to us in operating condition. Careful planning and close co-operation with us on the part of the stoker manufacturer enabled us to accomplish this result.



Front View of Stoker

We started three or four weeks ahead of the arrival of the stoker equipment, to do a great deal of preliminary work on Saturday afternoons and Sundays, when it is our custom, in the non-heating season, to either bank the unit or to shut it down entirely. The preliminary work done during such times included temporary removal of the hand grates each week to make the necessary excavations within the area of the firebox to provide for the additional setting height required and the foundations for the stoker; piercing a hole in the rear boiler wall; excavating and installing an air duct made of sewer pipe up to within a few inches of the front of the bridge wall; excavating in front of the boiler and concreting of the new stoker floor line; running all steam and exhaust lines for the forced draft fan and stoker up to within a few feet of the location of this equipment. At the end of each week-end thus spent in preliminary work, the hand-fired grates were replaced and the excavation in front boarded over so the boiler could be put in service for the next week's run.

An unusual and unlooked for difficulty was encountered during the progress of the excavation work when a tunnel some 8 ft. wide, 8 ft. deep and 12 ft. long was discovered immediately below the firebox. It was necessary to span this gap with steel beams as a starting point for the stoker foundations.

As a result of this preliminary work, when the stoker arrived at our plant it was then possible, between Saturday morning and Monday afternoon, to do the following:

(1) Remove permanently the hand-fired equipment.
(2) Pour the stoker foundation of quick-setting cement.
(3) Erect the stoker
(4) Rebuild a section of the side walls, bridge wall and front walls where necessary
(5) Make the final piping connections.

The equipment was ready to operate, as scheduled, on Tuesday morning but inasmuch as the weather at that time was mild and we had a locomotive placed adjacent to the plant as insurance against insufficient steam, we elected to dry out the new brick work for a few days before placing it in service.

Although we do not recommend waiting until too late in the fall before making changes such as this to your only boiler, we believe that our experience is interesting and shows what actually can be accomplished through proper co-operation and planning between the purchaser and the equipment manufacturer. Situations of this kind are sometimes unavoidable and, in such cases, a great deal of time can be saved by doing as much of the work as possible before the new equipment arrives.

Fig. 1—The firing aisle at Barking Station

An Important Development *in* Traveling Grate Stoker Practice

Our British correspondent reviews recent developments in the forced-draft, traveling grate stoker—as exemplified in the design of a new stoker of this type recently brought out in England

FOR over three quarters of a century, the traveling grate stoker has been recognized as one of the principal mechanical means for firing coal under steam boilers—particularly under water-tube and other types of externally fired boilers. This stoker was originated in England by John Juckes in 1841, since which time there have probably been more traveling grate stokers installed than of any other type.

The introduction of pulverized coal firing brought new standards of fuel burning efficiency, and developments in this new phase of combustion gave impetus to improvements in the older methods of firing coal.

Thus, during the past two years a great advance has been made in traveling grate stoker design through the development and wide adoption in England and throughout Europe, of the "Type L" stoker, manufactured by the Underfeed Stoker Company, Ltd.

As the result of this development, a single stoker of any required width may be constructed, with absolutely uniform distribution of the air for combustion, both longitudinally and transversely, over the entire grate area. At the same time, a simple and unique design provides for the automatic and continuous handling of the siftings or riddlings without the use of the usual complicated and troublesome ash riddlings discharge gear.

Before the introduction of the flat suspended combustion arch, the width of traveling grate stokers was limited to about eight feet as this figure represented the practical limits of the sprung arch.

Even today in a number of the power stations in the world using chain grate stokers, relatively small boilers of 50,000 to 100,000 lb. evaporation per hour operate with several stokers placed side by side. There are many obvious objections to this design, for example, the enormous waste in the combustion chamber as represented by the heavy and costly brickwork required to

We have fads in engineering practice, fads in steam plant design and fads in fuel burning methods. Many an engineer wishing to keep "up-to-date," has demanded pulverized fuel apparatus when a good stoker would better meet his needs. We ofttimes hear it said that the chain grate is becoming obsolete, because pulverized fuel firing and modern underfeed stokers have set standards too high for the chain grate to follow. This article reviews the revival of the traveling grate stoker abroad and the development of designs which are applicable to large boilers and the use of highly preheated air.

make the separate arches. Flat suspended furnace arches are now standard in all large installations so that with the "Type L" design any width of

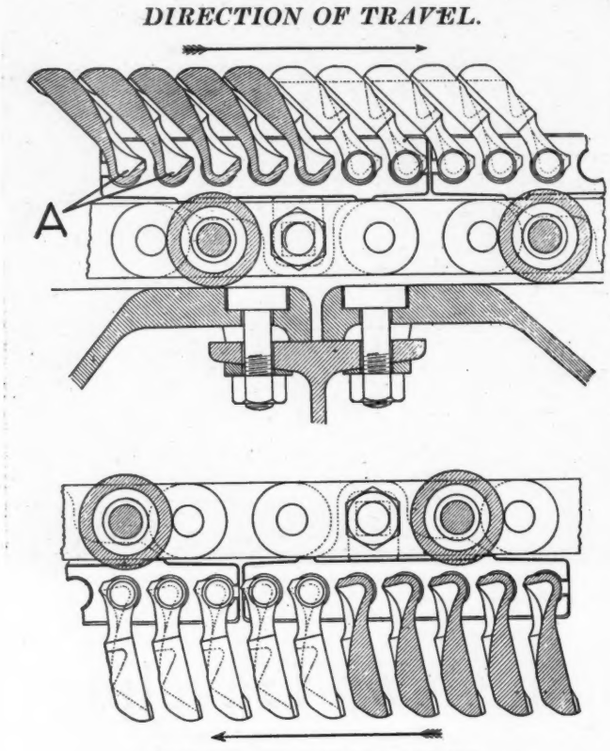


Fig. 2—Cross section showing position of grate bars on both forward and return travel. The curved lips A catch the siftings and discharge them to a hopper (shown in Fig. 4) as the grate turns down around the rear drum

stoker, 30 feet or more, can be constructed. Therefore, large boilers of 200,000 lb. evaporation per hour and over can now be operated with a single traveling grate stoker.

In designing these very wide units, however, another serious problem was encountered, the fact that by any of the usual methods of introducing the air supply from the stoker sides, it was impossible to give uniform rates of combustion over every point of the stoker width, since less air was delivered at the center of the grate. This difficulty has been completely eliminated in the "Type L" stoker, which embodies a number of ingenious detail designs which will be described in turn.

The grate surface of this stoker is composed of cast iron bars, or "louvres" constructed on an entirely new principle (Fig. 2). These bars are arranged transversely in sections the full width of the grate, to which they are attached by pivots, engaging in small carrier bars. In forming the actual grate surface these transverse parallel bars lie back on one another at an angle of about 45 deg. to the horizontal, with air spaces formed between them. The coal, introduced as usual through a hopper at the stoker front, burns as it travels, the remaining ash being discharged over the rear as the grate passes round the rear drum.

These swinging louvres, which give the name to the stoker ("L" or "Louvre"), are provided at their lower ends with projecting curved lips which catch the siftings and dust. These lips are marked A in Fig. 2.

As the grate travels down and around the drum at the rear, all the bars swing down on their pivots, hanging quite free and vertical on the return travel. The result is that the riddlings or siftings are discharged automatically and continuously from these curved lips into a hopper (shown in Fig. 4) arranged under the rear of the stoker and immediately adjacent to the ash hopper. No solid material passes down into the wind box, thus, special mechanically operated riddlings discharge gear—particularly liable to breakdown—is eliminated altogether, the bars which comprise the grate, carrying out this function. Further, by the use of free swinging loose links, any partial burning out, distortion or other disarrangement of the grate, does not alter the air space—since the links merely lie at a different angle which will represent the position which is correct for the changed conditions. Thus, one of the inherent weaknesses of most traveling grate stoker designs is overcome. Furthermore, ash and clinker cannot remain between adjacent bars because the links always swing wide open on the return travel. By means of two compartments at each side, the forced draft fan discharges direct into one very large and simple wind box or plenum chamber of ample height and capacity extended for the full width, and almost the entire length of the grate. Underneath the grate, the entire area is divided, both longitudinally and transversely, into a series of compartments all opening at the bottom to the windbox, and each serving with air, its own section of the grate surface above. Inside these compartments, close to the grate, are a number of small shutters, arranged in rows and operated together by common shafts projecting from one side

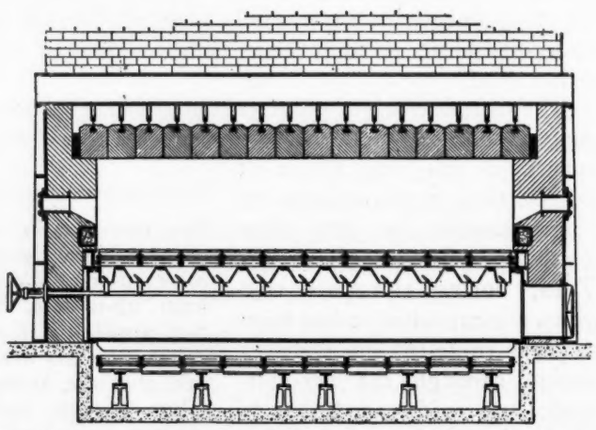


Fig. 3—Cross section showing the means of controlling a series of air valves

of the setting and fitted with hand wheel controls (Fig. 3). By operating these hand wheels, the air supply valves are opened or closed. Thus, accurate

and independent control of the air supply is obtained at different sections of the grate length by adjusting these wheels which are located along the side of the stoker, each hand wheel corresponding to one section of the grate length. This design provides uniformity of air supply over the entire width, with a simple type of wind box always free from riddlings, no matter how wide the stoker may be.

For stokers over 15 ft. 0 in. another characteristic feature is that the grate is made on the twin principle (Figs. 5 and 6); that is, two independent grates are placed side by side within the same setting. This arrangement has many advantages, for example, since the span of the supporting beams is halved, a much lighter and more efficient type of construction can be used, free from excessive bending or twisting stresses. Each grate functions as a separate and independent unit in so far as the driving mechanism is concerned. Further, the coal hopper is divided into halves, each with its own coal regulating shutter and cut-off gate and if necessary, one grate may be operated when the other is stopped, with the air supply controlled accordingly, just as the operation of each grate may be altered slightly to suit possible variations in the quality or size of the coal in the two side by side bunkers generally employed for modern wide settings.

Since its introduction only about two years ago, the "Type L" stoker has been such a success that a large number have already been sold in Great Britain, France, Belgium, Italy, Spain and Japan, both for power stations and industrial establishments. These include some of the most important power stations in Great Britain, for example, the Barking plant of the County of London Electric Supply Company, Ltd., a notable installation, because air heating is being used with air at an average temperature of 500 deg. fahr. delivered to the stoker. The advantages of air preheating being fully recognized, the "Type L" stoker was designed to permit the use of highly preheated air.

In glancing through the long list of "Type L" stokers operating in Great Britain alone one finds every possible degree of coal being employed, such as extremely difficult anthracite culm, (that is fines) slacks from almost every coal field, including the North-East Coast, Lancashire, Yorkshire, Kent, the Forest of Dean, Scotland, Somerset, South Wales and the Midlands area, in every degree of quality as regards calorific value, ash, melting point of the ash, volatile matter, and coking characteristics. It may be stated that many British coals are extremely difficult to burn efficiently because of the high ash content and the peculiar coking properties. Further, in a number of cases the ash of British coals is abnormal as regards the melting point under certain conditions, and this explains the many difficulties that have been experienced with certain types of stokers that have operated extremely well under American conditions but have been a complete failure with many varieties of British coal.

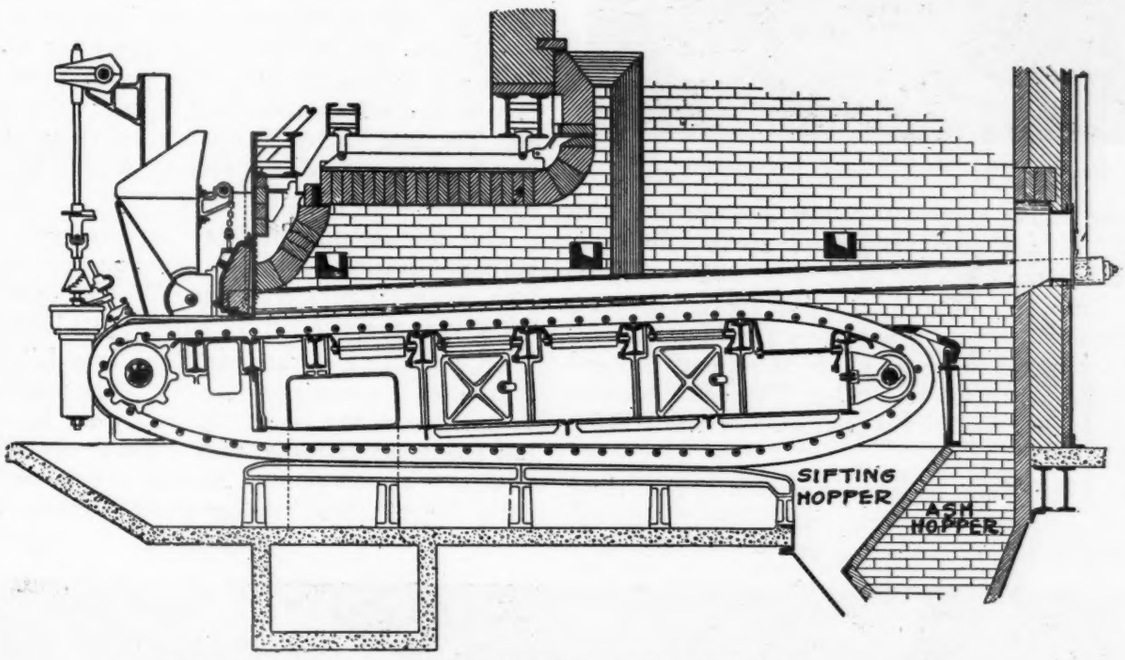


Fig. 4—Sectional side view of stoker showing separately controlled, transverse air valves

With regard to the size of individual units, great interest attaches to two "Type L" stokers now under construction for the London Power Company, Ltd., to be used at their Deptford E. Power Station. Each stoker is 31 ft. 0 in. wide, with 700 square feet total grate area and will serve boilers operating at 200,000 lb. normal evaporation per hour, the steam pressure being 320 lb. gage with 700 deg. fahr. superheated steam temperature. Multiple plate type air pre-

heaters will heat the combustion air to 250 deg. fahr.

These are the largest traveling grate stokers ever erected and the present installation was made following the highly successful results at Deptford with three "Type L" stokers started up in July 1928. These first machines are 19 ft. 0 in. wide and 18 ft. 0 in. long (342 square feet grate area), operating boilers of 80,000 lb. evaporation per hour normal, with a steam pressure of 325 lb. per square inch and preheated air at 280 deg. fahr. The fuel burned is mostly Scotch Washed Pea Coal and Northumberland Slack.

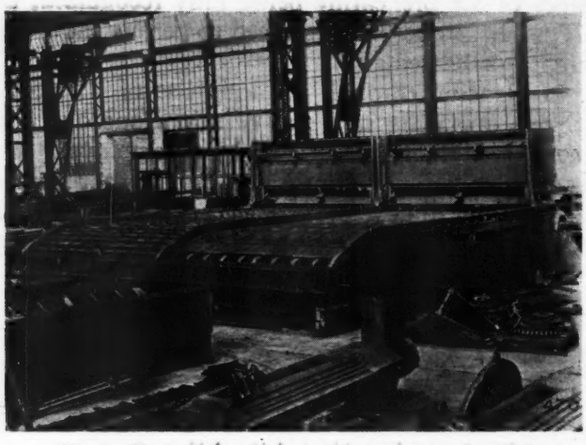


Fig. 5—Twin Stoker 31 feet wide under construction

One of the most interesting installations of these stokers is at the Barking Super-Power Station, already mentioned, situated on the Thames near London. This installation (Fig. 1) consists of six stokers, each of 332 square feet grate area, and operating "Yarrow" boilers with a normal evaporation of 85,000 lb. per hour and 125,000 lb. overload rating. Plate type air preheaters deliver combustion air to the stokers at 500 deg. fahr. Northumberland Slack and Scotch Pea Coal is burned. The complete installation has a normal evaporation of 510,000 lb. of water per hour and 750,000 lb. overload. This installation was placed in service in July, 1927 and has been running since with the greatest success.

The Barking Power Station is situated on a site of about 100 acres at a place called Creekmouth, Barking, with a frontage to the Thames of about 2,100 feet. The station is designed for ultimate extension to 600,000 kw., the present plant being 200,000 kw. which however is already being extended. The first section is operated with mechanical stokers and the second section with "Lopulco" pulverized fuel systems.

This first section has two separate sets of six boilers operating at 375 lb. pressure and 700 deg. fahr. steam temperature. The "Type L" stokers are operating one section of the boilers, that is six in all.

An interesting feature of these "Type L" stokers at Barking is a water cooling box (shown in Fig. 6), in series with the boiler, placed in the brickwork just above the grates, so as to prevent any adhesion of clinker at this point. Because of the size of the units, the stokers at Barking are of the twin variety.

(Continued on page 53)

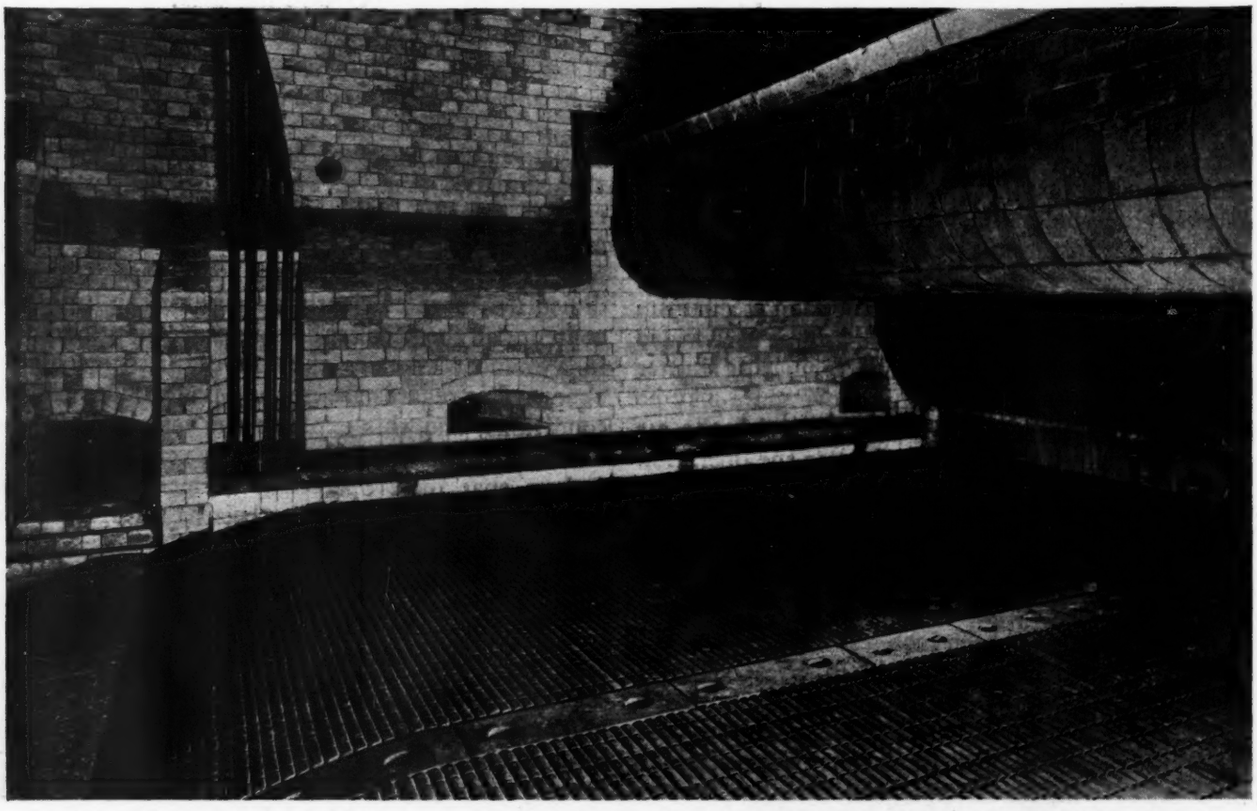


Fig. 6—Interior of combustion chamber at Barking Station, showing twin stoker and arch arrangement

NEWS

Pertinent Items of Men and Affairs

Iron and Steel Exposition Buffalo--June 16 to 20

Under the auspices of the Association of Iron and Steel Electrical Engineers, comprising the executives, managers and engineers of the Steel Industry, the Iron and Steel Exposition will be held at the Broadway Auditorium, Buffalo, N. Y., from June 16th to 20th, inclusive.

An exhibition of equipment applicable to the steel industry has been planned, over 50,000 square feet of floor area having been set aside for this purpose.

Coincident with this Exposition, the convention of the Association of Iron and Steel Electrical Engineers will be held. The tentative program includes the following subjects which will be presented at the technical sessions:

Electric Welding and Heating.
Plasticity of Steel.
General Description of the most modern Steel Plants.
Gas Utilization in Iron and Steel Industry.
Gas Producers in Iron and Steel Industry.
Steam Generation and its Utilization in Iron and Steel Industry.
Use of Liquid Fuels in Iron and Steel Industry.
Mechanical and Electrical Maintenance Shop Practice.
The Use of Air and Gas Conditioning Apparatus for Iron and Steel Industry.
Topical Discussion: Problems in Furnace Installation, Operation and Maintenance in Iron and Steel Industry.
Use of Instruments and Control in Furnace Practice in Iron and Steel Industry.
Should Universities and Colleges create a Safety Engineering Course?

The Midwest Bituminous Coal Conference to be held at Purdue University, Lafayette, Indiana, April 9th to 11th inclusive will be under the direction of the Engineering Extension Department of Purdue University with the Coal Trade Association of Indiana, the Illinois Coal Bureau and the Fuels Division of the American Society of Mechanical Engineers, co-operating.

The tentative program includes papers on the following subjects:

Discussions of Economic Considerations to be taken into account in selecting coals. Various uses of Bituminous Coal including power, industrial and domestic uses.
Uses of Bituminous Coal as applied to ceramic, glass, gas and other industrial uses.
Mechanical Devices suitable for burning Bituminous Coal in semi-industrial and domestic installations.
Problems of Distribution and Marketing.
Research Problems of value to the Coal Industry.
Reconditioning existing plants and requirements of new plants to burn Bituminous Coal efficiently and smokelessly.

Public Utility Construction Program Exceeds Estimated Rate of Expansion

According to information received by the National Electric Light Association from companies representing 85 per cent of the light and power industry, the total estimated expenditures for new construction already made, or to be made by March 31st, will be $198,000,000. This amount is 10½ per cent higher than the amount expended during the first quarter of 1929. The information was obtained in response to a request of President Hoover's Business Survey Conference and in order to determine the actual progress in carrying out the construction program of the electric light and power utility companies for 1930.

On November 27th, 1929, the President was informed that the estimated total expenditures by the light and power companies for new construction, improvement, and expansion of their facilities during this year will be $865,000,000, not including expenditures for maintenance of existing facilities. This was 8 per cent higher than similar expenditures during 1929.

The fact that the expenditures for the first quarter of 1930 are estimated to be 10½ per cent higher than for the first quarter of 1929 indicates that the construction program has been accelerated.

Collins P. Bliss has been made dean of New York University Engineering College to succeed Charles H. Snow who will retire in April. Mr. Bliss has been associated with the university since 1896, serving first as instructor in mechanical engineering and since 1927 as associate dean.

Riley Stoker Corporation, Worcester, Mass., has announced that Harold G. Meissner has joined its New York office organization as sales engineer.

F. A. Schaff Elected President of The Superheater Co.

Frederick Alan Schaff has been elected President of The Superheater Company, New York, succeeding Mr. George L. Bourne, who has been elected Chairman of the Board of Directors. Mr. Schaff's headquarters will remain at the principal office of the company, 17 East 42nd Street, New York.

Mr. Schaff was born at Nelsonville, Ohio, May 24th, 1884, and was graduated from Purdue University in 1907. He spent several years in the Mechanical Departments of the Boston & Albany Railroad and the New York Central Lines. Following a period of several years' residence in Texas, in charge of business interests there, he became associated with The Superheater Company, in their Service Department, in 1913. He was elected Vice-President in 1915, in which capacity he has served until his election to the office of President.

The Girtanner Engineering Corporation, manufacturers of steam, water and vacuum pipe line conveyors, announce the moving of the main office of the company from 122 Greenwich Street, New York, N. Y., to their factory location at Palmyra, N. J.

Tennessee Coal, Iron & Railroad to Use Natural Gas

The Tennessee Coal, Iron & Railroad Company, one of the principal subsidiaries of the United States Steel Corporation, is reported to have awarded a contract to the Southern Natural Gas Corporation, which is controlled by Tri-Utilities Corporation, for supplying approximately four and one-half billion cubic feet of natural gas annually. Under the terms of the contract, the Southern Natural Gas Corporation will supply natural gas which will be distributed to the Tennessee Coal, Iron & Railroad Company for use in its Bessemer rolling mill, its Fairfield, Ala., and Ensley, Ala., plants and also for resale, for industrial use only, to other subsidiaries of the United States Steel Corporation in the Birmingham district.

The natural gas will replace fuel oil, producer gas and other fuels now used throughout these plants. Deliveries of gas are expected to begin in March.

J. B. Crane formerly High Pressure Specialist for Combustion Engineering Corporation, New York, has been appointed District Manager of that company's Pittsburgh office succeeding H. A. Telander, resigned.

M. F. Corin, who for fourteen years has been Philadelphia District Sales Manager for the Permutit Company, manufacturers of water treating equipment, has been appointed General Sales Manager, with headquarters at the company's main office in New York.

Mr. Corin will have supervision over 19 branch sales offices throughout the United States and numerous sales agencies in foreign countries.

The Electric Light and Power Industry

Basic information on the electric light and power industry as of December 31st, 1929, and issued by the Statistical ResearchDepartment of the National Electric Light Association is as follows:

1. Value of plants and equipment (estimated)	$11,031,000,000*
2. Total generating capacity in kw.	29,495,000
Steam	21,562,000
Waterpower	7,604,000
Internal Combustion	329,000
3. Total number of customers served	24,249,000
Farm customers (as reported by 208 companies only)**	(256,000)
Domestic customers	19,999,000
Commercial customers	
Large light and power	567,000
Small light and power	3,648,000
Others	35,000
4. Population in electrically lighted homes	84,000,000
5. Percentage of homes which are served with electricity	68%
6. Miles of transmission lines (11,000 volts and above) (circuit miles)	162,000*

* Subject to revision ** Included below

Bituminous coal production during the week ended February 8th, according to the Bureau of Mines, was estimated at 10,936,000 net tons as against 11,628,000 tons in the preceding week, a decrease of 6.0 per cent. The daily average production for the week ended February 8th was 1,823,000 tons as compared with 1,938,000 tons for the previous week and 2,102,000 tons for the corresponding week in 1929.

The total production of bituminous coal from April 1, 1929, the beginning of the current coal year, to February 8th was 449,510,000 net tons. Figures for recent corresponding periods are given below:

Net Tons	Net Tons
1928-29—436,158,000	1926-27—500,861,000
1927-28—407,456,000	1925-26—460,395,000

An Important Development in Traveling Grate Stoker Practice

(*Continued from page 50*)

Unfortunately it is not possible to give the full test results being obtained with these stokers. In fact, very little information has ever been made available concerning results at Barking, all the more regrettable as it is generally regarded as the most important installation in Great Britain. However, we are able to state that with regard to the performance of the "Type L" stokers the average net efficiency being obtained is above 85 per cent when burning the normal slack coals already mentioned, at an evaporation of 82,720 lb. of water per hour with preheated air at a temperature of 492 deg. fahr. This corresponds to a combustion rate of about 32.5 lb. per square foot of grate surface per hour, based upon the full length of the grate.

Some of the other noteworthy installations of "Type L" stokers at British stations are at the Dunston Power Station of the Newcastle-on-Tyne Electric Supply Company, where the combustion air is preheated to 300 deg. fahr, the Swindon Corporation Electricity Station, also with preheated air at 300 deg. fahr., the Lister Drive Power Station of the Liverpool Corporation, Wimbledon Power Station in London, and others. The London Power Company, in addition to Deptford, also have "Type L" stokers running at their Grove Road Station.

Equally interesting, is the fact that this stoker is being used more and more in large industrial establishments equipped with water-tube boilers.

It is interesting to note the wide application of this stoker for burning practically every kind of coal commercially available throughout the world.

A few of the foreign projects are the Imperial Steel Works, Japan; Colonial Sugar Refineries, Ltd.; Fiji Islands, and Arcos, Ltd. for Cheliabinsk in Siberia and Borsigs, Ltd. for Sumitomo in Japan. An installation of four stokers has been supplied to Constantinople, each unit having 186 square feet grate area and operating boilers of 44,092 lb. normal evaporation per hour and 55,115 lb. overload when burning Heracles coal with preheated air at 280 deg. fahr.

It is believed that the Barking plant of the County of London Electric Supply Company, where preheated air at 500 deg. fahr. is used, represents the highest air temperature so far attempted in stoker operation.

The salient features of this stoker may be summarized as:

1. ability to burn efficiently a wide variety of coals.
2. adaptability to the use of highly preheated air.
3. can be built in single units of practically any size.
4. self cleaning grate surface—handles own siftings continuously and automatically.
5. correct air space maintained under all conditions.
6. controlled air distribution over entire grate area.

Forty-nine Nations at World Power Conference

The United States of America will be one of the leading participants in the World Power Conference to be held in Berlin from June 16 to 25 next when engineers, economists, chiefs of industry, agricultural experts and specialists in education from forty-nine countries will be called together.

Officially known as the Second Plenary World Power Conference, the meeting will bring together the largest group of power-science savants ever assembled in the history of the world.

Cooperating with the German sponsoring group is an American Committee, of which the Hon. Robert P. Lamont, Secretary of Commerce of the United States, is Honorary Chairman and which has its headquarters in the Edmonds Building, Washington. The Chairman of the American Committee is O. C. Merrill of Washington, formerly executive secretary of the Federal Power Commission.

Discussion of the subjects coming up at the World Power Conference will be divided into four classes. Sources of Power will be in Class A; Power Production, Power Transmission and Storage will come under Class B; Utilization of Power will be in Class C and general subjects will come under Class D. A large corps of American scientists and engineers will prepare and present papers.

Water Softening Practice in Great Britain

13th February, 1930.

The Editor,
"Combustion," 200 Madison Avenue,
New York.

Sir,

With regard to my article on Water Softening Practice in Great Britain, in the issue of January last, I am informed by Messrs. Synthetic Ammonia & Nitrates, Ltd. of Billingham, Stockton-on-Tees, that there is an error.

The feed-water used in the 800 lb. pressure boilers is 100% pure, that is approximately half return condensate and the other half from low pressure evaporators, and no softened water is therefore being added to these boilers. The "Boby" water softening plant, which I mentioned, supplied to Messrs. Synthetic Ammonia & Nitrates, Ltd., is for dealing with another steam boiler installation at Billingham at a lower pressure, namely 275 lbs. per square inch.

I should be glad, therefore, if you would publish this letter of mine so as to put the matter absolutely straight, as naturally everyone is only too anxious to have the facts right and there has been some slight misunderstanding in the matter.

Yours,
(*Signed*) DAVID BROWNLIE.

NEW CATALOGS AND BULLETINS

Any of the following literature will be sent to you upon request. Address your request direct to the manufacturer and mention COMBUSTION Magazine

Air Cooled Furnace Walls

De Wolf air cooled furnace walls are described in bulletin No. 1. The design is offered to provide a structure which is slightly flexible and resilient so as to accommodate the expansion and contraction due to temperature changes. Cover plates are attached to the outside of I beams, which form the vertical members of the wall, and the air for combustion is circulated through the ducts thus formed. In this manner, the wall is cooled and the air is preheated, at the same time. 8 pages, 8½ x 11—De Wolf Furnace Corporation, 119 East Main St., Rochester, N. Y.

Burners—Oil, Coal and Gas

Peabody Burners for oil, coal and gas are presented in a new Bulletin No. 601. Individual burner designs are shown for each fuel and in addition several designs provide for combination firing of gas and oil, or, gas, oil and pulverized coal, all through the same burner. 8 pages, 8½ x 11—Peabody Engineering Corporation, 110 East 42nd St., New York, N. Y.

Centrifugal Blowers

De Laval centrifugal blowers and compressors for gas plants, blast furnaces and general industrial service, are shown in new catalog F. These blowers are built in both single stage and multi-stage types for all pressures up to 100 lb. per sq. in. They are direct connected to a steam turbine drive. The catalog is well illustrated with views of equipment and data charts. A chapter on the compression of gases, is included. 48 pages and cover, 8½ x 11—De Laval Steam Turbine Co., Trenton, N. J.

Centrifugal Pumps

Bulletin 200, the first of a series of similar bulletins, which will eventually cover the entire line of Goulds Single—and Multi-Stage Centrifugal Pumps, is devoted to those types and sizes which take care of the majority of pump requirements encountered in industry. Eight full page charts are presented to assist in selecting the proper pump for a particular service. Specifications, descriptions and illustrations of a wide range of pumps are included. —40 pages and cover, 8½ x 11—Goulds Pumps, Inc., Seneca Falls, New York.

Coal Crushers

The new "S" Type American Ring Crusher is presented in a descriptive bulletin. Preparing coal at the plant, to the size that best suits the stoker, not only improves the combustion but also makes possible the use of a wider range of coals. Ash pit and excess air losses are reduced through the proper sizing of coal. The details of the ring crusher are shown together with some interesting illustrations of typical installations. 8 pages, 8½ x 11—American Pulverizer Company, 1249 Macklind Ave., St. Louis, Mo.

Feed Water Treatment

The Korite System of Feedwater treatment, described in a new bulletin, is offered to avoid scale, corrosion and caustic embrittlement in the operation of modern boilers at high ratings and high pressures. Korite is described as soluble, non-volatile, non-acid and non-caustic. The treatments are prescribed and controlled by indicator tests. A variety of Korite chemical products for industrial use are also briefly presented. 68 pages and cover, 7¾ x 10½—Korite, Inc., 89 Bickford St., Boston, Mass.

Forged Steel Boiler Nozzles

Bulletin 29-13 describes Taylor Seamless Forged Steel Boiler Nozzles. Modern technique in riveted and welded vessel building has advanced, of necessity, to meet the requirements for safety and efficiency at the higher pressures. As a result, seamless forged steel nozzles have rapidly supplanted cast or built-up outlets. Standard flange data sheets are included. 22 pages, 8½ x 11—Taylor Forge & Pipe Works, Chicago, Ill.

Induced Draft Stacks

Thermix Stacks are presented in Catalog No. 14. The basic idea behind the design of the different types of Thermix stacks is to combine, into a single unit, the various interrelated parts which make up the complete producing apparatus. The No. 4 stack also provides means for mechanically removing cinders and dust from the gases. The catalog is well illustrated and many typical layouts are included. 24 pages and cover, 8½ x 11—Prat-Daniel Corporation, 183 Madison Ave., New York.

Instruments and Regulators

Defender Combustion Appliances, Regulators and Boiler Room Instruments are fully covered by a series of bulletins contained in a loose leaf cover. The Defender line of products is unusually comprehensive and includes combustion control systems, thermometers, pyrometers, gages, Orsat apparatus and various types of control valves. Numerous illustrations show the products and the descriptive matter is quite complete. 92 pages and cover, 8½ x 11—The Defender Automatic Regulator Company, St. Louis, Mo.

Refractories

"Modern Refractory Practice" is the title of a handsome reference book and catalog which covers the general subject of refractories with special reference to Harbison-Walker products. A wide range of materials is presented, including fireclay, high-alumina, magnesite and chrome refractories. Chapters are also devoted to high temperature cements and acid-proof brick. Another important chapter covers the use and application of refractories. General technical information is included in the final chapters. This book is a definite contribution to the subject of refractories and their use. 180 pages and cover, 8½ x 11—Harbison-Walker Refractories Co., Pittsburgh, Pa.

Steam Separators

Cochrane Steam Separators are illustrated and described in new bulletin No. 671 which represents a comprehensive treatise on the subject. Principles of design, construction details and application arrangements are well covered. Separate chapters on Oil Separators, Steam Purifiers, Drainers and Traps are included, together with data sheets of standard flange dimensions. 92 pages, 8½ x 11—The Cochrane Corporation, 17th Street and Allegheny Ave., Philadelphia, Pa.

Steel Grating and Flooring

Steel Grating and open flooring are finding increasing application in the steam plant. The open areas admit both air and light and the surface is non-slip and provides the workers a safe foothold on floors and stair treads, even when the surface is wet or greasy. The advantages of Blaw-Knox Electroforged Steel Grating are well illustrated and described in a new folder. A table of safe loads is included for the architect or designing engineer. 4 pages—Blaw-Knox Company, Pittsburgh, Pa.

Steel Plate Fans

Clarage Steel Plate Fans are illustrated and described in Catalog No. 33—Both forced draft and induced draft are discussed and steel plate fans designed for both types of service, are presented. Construction details are shown and charts and tables are included to assist in selecting fan sizes and to determine performance characteristics. 20 pages, 8½ x 11—Clarage Fan Company, Kalamazoo, Mich.

Underfeed Stoker

A new bulletin describes the C-E Firetender Stoker which was developed to meet the demand for an automatic underfeed stoker for firing small boilers developing from 15 to 100 boiler horsepower, such as are used in apartment houses, hospitals, schools, greenhouses, laundries, etc. The stoker burns bituminous coal and is applicable to practically every standard make of heating or power boiler. The machine is self contained and the stoker and forced draft fan are driven by an electric motor. 4 pages, 8½ x 11—Combustion Engineering Corporation, 200 Madison Ave., New York.

Valves

Homestead Valves are presented in Catalog No. 35. A wide range of designs is offered and the various metals used include, brass, semi-steel, acid resisting bronze, cast steel and special alloys. Working pressures of over 3000 lb. are provided for. Many illustrations are included to show details of design. 52 pages and cover, 6 x 9—Homestead Valve Manufacturing Co., Coroapolis, Pa.

Water Gages

Reliance Water Gages are built for a wide range of pressures, up to 1500 lb. per sq. in. In the gages using round gage glass, breakage is reduced to a minimum by careful design and machining accuracy which frees the gage glass from all strain due to mis-alignment—the most common cause of glass breakage. The high pressure gages use special flat glass, protected from the action of steam and water, by clear mica. These high pressure gages are special and are built on order only. Several descriptive folders are available. Reliance Gauge Column Company, 5902 Carnegie Ave., Cleveland, Ohio.

Water Softening Systems

The WE-FU-GO Water Softening and Purifying System is described in Bulletin 210. This system is of the intermittent type in which definite quantities of water are treated, thus maintaining uniform water regardless of variation in the quality of the raw water or the rate at which the treated water is used. The reaction tanks act as storage tanks, consequently a supply of purified water is always available. The details of the system are illustrated and typical installation views are included. 12 pages, 8½ x 11—Wm. B. Scaife and Sons Co., Oakmont, Pa.

REVIEW OF NEW TECHNICAL BOOKS

Any of the books reviewed on this page may be secured from
In-Ce-Co Publishing Corporation, 200 Madison Avenue, New York

Electric System Handbook

By C. H. Sanderson

THIS book answers the increasing demand for a handbook which will tell the story of the electric system as a whole, in logical sequence and in a simple form readily understandable by every one whether he possess a technical education or not. It gives complete and authoritative information on every phase of the work—the fundamentals of electricity; generating, transforming and auxiliary equipment; central and sub-stations; power lines; design, construction, operation, repair, inspection—everything you can possibly want to know—told so you can grasp it easily, and quickly, accurately and effectively apply it to your own work.

This handbook, by reason of its comprehensiveness, is of value to every man, no matter what his connection with electric system work. Students of engineering, operatois, inspectors, maintenance and test department employees, engineering draughtsmen—all will find here the answers to their particular problems and also a wealth of generally useful information on the field at large.

The topics have been presented in a manner and sequence which will enable the reader to pass logically from each section to the succeeding one. Higher mathematics is entirely omitted and all technical expressions are fully explained. It provides, ready for quick reference, the answer to any problem, large or small, that may arise to puzzle you.

This book is attractively bound in semi-stiff fabrikoid covers, 5 x 7¼ in. overall, and contains 1167 pages including a well arranged and comprehensive index. The price is $5.00.

The Universe Around Us

By Sir James Jeans

WHILE this book has no immediate relationship to the field of combustion and steam generation, its general scientific interest and value is such that engineers in every field should make a definite point of reading it at the first opportunity.

No attempt is made to explain in detail the more recondite aspects of astronomy. The descriptions given of the Einstein Theory and Schrodinger's wave theory of the electron are models of lucidity and are nicely measured to the intelligence of the reader who has no specialized knowledge.

By adhering to this method throughout, Jeans has managed to give an amazingly complete picture of the universe as it appears to the astronomer, without in any way straining his reader's attention. Of course, more than astronomy enters into it: physics, geology, chemistry and pure mathematics each contributes its share. Whenever possible, debatable questions have been approached from an historical point of view, so that the book moves forward like a story.

Seldom has a scientific book received such consideration from the reviewers of newspapers and general magazines, as well as from eminent figures in the literary and scientific fields. Invariably these reviews have been high commendary. Henry Fairfield Osborn has this to say of it. "Sir James Jeans is one of the most brilliant and versatile thinkers and writers of the present day. He has, moreover, the very rare gift of making extremely difficult subjects comprehensible to the intelligent lay reader. His volume, *The Universe Around Us*, brings us absolutely up-to-date in the most progressive sciences of modern times, astronomy and physics, clearly presenting the very latest discoveries which transcend our powers of imagination."

This book is bound in cloth covers, 6 x 8¾, and contains 331 pages. The price is $4.50.

Metallurgy of White Metal Scrap and Residues

By Edmund Richard Thews

ALTHOUGH the scrap and residue treating industries in this country have been assuming a rapidly growing importance, there is little published information available on the technology involved.

This book will, therefore, be welcomed by those who are interested in this phase of metallurgy. It covers comprehensively the treatment of all white metal wastes including the zinc and aluminum materials, and gives particular attention to the condition and requirements of the small and medium size plants working up their own scrap and residue and operating either independently or in conjunction with larger establishments.

This book is bound in cloth covers, 6 x 9, and contains 375 pages. The price is $5.50.

PATENTS

Recently granted, and of Interest to our Readers.

Printed copies of Patents are furnished by the Patent Office at 10 cents each.
Address the Commissioner of Patents, Washington, D. C.

UNITED STATES PATENTS

Issued December 31, 1929

1,741,217. Superheater Tube and Method of Making Same. William H. Winslow, Chicago, Ill., assignor to Foster Wheeler Corporation, New York, N. Y., a Corporation of New York. Filed Oct. 29, 1921. Renewed June 1, 1929.

1,741,663. Method and Apparatus for Utilizing Waste Heat. Herman B. Smith, Plainfield, N. J., assignor to The Babcock & Wilcox Company, Bayonne, N. J., a Corporation of New Jersey. Filed April 6, 1927.

1,741,718. Furnace Wall and Baffle. David S. Jacobus, Montclair, N. J., assignor to The Babcock & Wilcox Company, Bayonne, N. J., a Corporation of New Jersey. Filed Nov. 27, 1925.

Issued January 21, 1930

1,744,165. Furnace Wall. David S. Jacobus, Jersey City, N. J., assignor by mesne assignments, to Fuller Lehigh Company, a Corporation of Delaware. Filed May 5, 1923.

1,744,185. Air-Cooled Furnace Block. Frank H. Waite and George W. Davey, Long Island City, N. Y. Filed Oct. 8, 1925.

1,744,407. Hopper. John B. Meccia and William Reynolds, Chicago, Ill. Filed Feb. 11, 1929.

1,744,452. Boiler-Furnace Preheater. Wyllys E. Dowd, Jr., New York, N. Y., assignor to Foster Wheeler Corporation, New York, N .Y., a Corporation of New York. Filed Feb. 16, 1926.

1,744,595. Stoker. Edwin Archer Turner, New York, N. Y., assignor to The Standard Stoker Co., Inc., a Corporation of Delaware. Filed Dec. 3, 1929.

1,744,599. Treating Hydrocarbon Oil. Claude W. Watson, Port Arthur, Texas, assignor to The Texas Company, New York, N. Y., a Corporation of Delaware. Filed Nov. 11, 1927.

Issued January 28, 1930

15,572. Apparatus for the Manufacture of Carbonized Fuel. Steward Roy Illingworth, Cardiff, Wales, assignor to the Illingworth Carbonization Company, Limited, Manchester, England. Filed Sept. 3, 1929, and in Great Britain Oct. 29, 1923.

1,744,895. Pulverizing Machine. Paul Arthur Hirsch, New York, N. Y. Filed Nov. 15, 1928.

1,744,927. Pulverizer. Robert Sinclair, New York, N. Y., assignor to United Combustion Engineers, Inc., New York, N. Y., a Corporation of New York. Filed June 19, 1928.

1,744,962. Oil Burner. Forrester L. Hammer, Branford, Conn. Filed June 9, 1928.

1,745,032. Hydrocarbon Burner. John B. Shadyac, Littleton, N. H. Filed Feb. 9, 1928.

1,745,062. Safety Device for Liquid-Fuel Burners. John Scheminger, Jr., Providence, R. I., assignor, by mesne assignments, to Petroleum Heat and Power Company, New York, N. Y., a Corporation of Delaware. Filed May 10, 1926.

1,745,093. Fluid Heater. George J. Heimberger, Bayonne, N. J., assignor to The Babcock & Wilcox Company, Bayonne, N. J., a Corporation of New Jersey. Filed Sept. 27, 1927.

1,745,178. Liquid-Fuel-Burner Control. Ira E. McCabe, Chicago, Ill. Filed Dec. 6, 1926.

1,745,308. Boiler Construction. Montague V. Milton, Toronto, Ontario, Canada. Filed Jan. 24, 1927.

1,745,327. Boiler Cleaner. Norman L. Snow, Detroit, Mich., assignor to Diamond Power Specialty Corporation, Detroit, Mich., a Corporation of Michigan. Filed Dec. 1, 1924.

1,745,329. Burner Nozzle. Forrester L. Hammer, Branford, Conn. Filed Apr. 21, 1927.

1,745,331. System of Regulation and Control for Liquid-Fuel-Fired Furnaces and the Like. Frank F. Parker, San Juan Bautista, Calif. Filed Feb. 14, 1927.

1,745,337. Zeolite and Method of Making Same. Svein Dahl-Rode, Philadelphia, Pa., assignor to Cochrane Corporation, Philadelphia, Pa., a Corporation of Pennsylvania. Filed Dec. 23, 1924.

Issued February 4, 1930

17,577. Heating Air and Gases. Waldemar Dyrssen, Sharpsburg, Pa., assignor to Blaw-Knox Company, Pittsburgh, Pa., a Corporation of New Jersey. Filed June 24, 1927.

1,745,383. Boiler for High Pressure. Johannes Ruths, Djursholm, and Nils Hezekiel Frenne and Mattias Backstrom, Stockholm, Sweden, assignors, by mesne assignments, to Ruths Accumulator Aktiebolag, Stockholm, Sweden. Filed Feb. 28, 1923, and in Sweden Feb. 22, 1922.

1,745,429. Axial-Flow Steam Turbine. Alf Lysholm, Stockholm, Sweden, assignor to Aktiebolaget Ljungstroms Angturbin, Stockholm, Sweden, a Joint Stock Company of Sweden. Filed May 3, 1928, and in Sweden May 11, 1927.

1,745,474. Heat Insulating Casing, Perry Cassidy, Darien, Conn., assignor to The Babcock & Wilcox Company, Bayonne, N. J., a Corporation of New Jersey. Filed Sept. 9, 1926.

1,745,484. Soot Cleaner for Boiler. Isaac Harter, Dongan Hills, N. Y., assignor to the Babcock & Wilcox Company, Bayonne, N. J., a Corporation of New Jersey. Filed June 18, 1923.

1,745,563. Water Softener. Edward T. Turner, Dayton, Ohio. Filed Dec. 10, 1928.

1,745,597. Feed-Water Heater. Edmund H. Blunt, New York, N. Y. Filed Dec. 1, 1922.

1,745,613. Exhaust Steam Injector. Joseph F. Griffin, Teaneck, N. J., assignor to The Superheater Company, New York, N. Y. Filed Dec. 28, 1927.

BRITISH PATENTS

Accepted December 24, 1929

301,431. Improvements in and relating to Furnaces. The British Thomson-Houston Company, Limited, at Crown House, Aldwych, London, W.C.2. Assignees of Carl Laurencious Ipsen, and James Lee McFarland of Lakewood Avenue, of 1268, Parkwood Boulevard, Schenectady, N. Y.

302,718. Improvements in Steam Generating and Supply Plants. Franz Jaschik, of Roonstrasse 24, Kattowitz, Poland.

302,903. Improved Means for Regulating the Heating Effect in Apparatus Heated with Steam. Curt Rosenblad, of Vapnaregatan, 1, Stockholm, Sweden.

308,211. Improvements in or relating to the Regulation of Steam Power Units. Ruthsaccumulator Aktiebolag, of 1A, Eriksbergsgatan, Stockholm, Sweden.

314,007. Improvements in Tuyeres particularly applicable to Underfeed Stokers. American Engineering Company, of Aramingo Avenue and East Cumberland Street, Philadelphia, Pa.

323,099. Improvements in or relating to Steam Separators. Cockburns Limited, and Donald MacNicoll, both of Clydesdale Engineering Works, Cardonald.

323,146. Improvements in and relating to Steam Boilers, especially Marine Boilers, with Indirect Generation of the Working Steam. William Warren Triggs, of Marks & Clerk, 57 & 58, Lincoln's Inn Fields, London, W.C.2.

323,150. Improvements in and relating to Apparatus for Distributing Crit, Sand and like Materials, on Roads and other Surfaces. Thomas Coleman and Sons, Limited, Alfreton Road, Derby, and Frank Coleman.

323,155. Improvements in or relating to the Elevating Mechanism for the Loading Hoppers of Concrete Mixers and like Machines. Charles Henry Fowler and George Hobson, both of Steam Plough and Locomotive Works, Hunslet, Leeds, County of York.

323,159. Improvements in Ore Reducing Furnaces. Cayzer Tin Smelting Company Limited, of Barsdorf's Buildings, Marshall Street, Johannesburg, South Africa.

Accepted January 2, 1930

312,167. Improvements in and relating to Steam Condensers. The British Thomson-Houston Company Limited, at Crown House, Aldwych, London, W.C.2.

303,810. Separating Apparatus for the Treatment of Ores, Coals and other similar Materials. Leon Hoyois, of 92, Chaussee de Ransart at Gilly, Belgium.

304,588. Improvements in Steam Generators. Trajan Vuia, of 7, rue de Toulon, Garches, Seine et Oise, France, and Emmanuel Yvonneau, of 35, Avenue du Parc Montsouris, Paris, France.

309,177. Improved Process of an Oven or Kiln for Baking Pulverulent Materials such as Limestone. Julien Bellay, of No. 98, Avenue d'Auderghem, Brussels, Belgium.

323,273. Improvements in and relating to the Control of the Working Steam in High-Pressure Locomotives with Interstage Superheating. Sir George Croydon Marks, of 57 and 58, Lincoln's Inn, London, W.C.2.

Correction

The advertisement of the Ellison Draft Gage Company, which appeared on page 64 of February COMBUSTION, incorrectly listed the price of the Ellison two-pointer gage as $27.50 to $55.00 and the three-pointer gage as $27.50 to $80.00. The correct prices of the two-pointer and three-pointer gages are $55.00 and $80.00 respectively.